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INTELLIGENCE AND SOCIAL VALUATION

A PRACTICAL METHOD FOR THE DIAGNOSIS
OF MENTAL DEFICIENCY AND OTHER
FORMS OF SOCIAL INEPTITUDE

BY
RICHARD A. BERRY, M. D.

WITH
S. D. FORTES



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Intelligence and Social Valuation

A PRACTICAL METHOD FOR THE DIAGNOSIS OF MENTAL DEFICIENCY AND OTHER FORMS OF SOCIAL INEFICIENCY

INTRODUCTION

It has been pointed out by a writer (1) in the "Fortnightly Review" for January, 1917, that the "root problem of all the after-war problems is the conservation of the wealth of the Nation of to-morrow which resides in its boys and girls of today. The future of the country depends on their future."

Whilst it is impossible to enumerate here the many problems which are intimately associated with the question of child conservation, there is no doubt that one of the most pressing of these problems—whether it be regarded from its medical, sociological, or educational aspects—is that of mental deficiency. As it is clear that post-war reconstruction will depend on the mentality and efficiency of the people, it follows that any community which comprises an appreciable percentage of unrecognized mentally defective persons will be severely handicapped in the work of social reconstruction unless such persons can be recognized and treated.

Definitions of Feeble-Mindedness

Feeble-mindedness or moronity has been variously defined. The legal definition as given in Clause 1 of the Mental Deficiency Act of 1913, England, is:

"Persons in whose case there exists from birth, or from an early age, mental defectiveness not amounting to imbecility, yet so pronounced

that they require care, supervision, and control for their own protection or for the protection of others."

Tredgold (2) suggests a definition based on industrial ability. He says:—"The term 'mental deficiency', in my opinion should be restricted to those persons who are so lacking in general mental capacity, and in commonsense, that they are incapable of subsisting by their own unaided efforts."

The British Royal Commission in 1908 defined feeble-mindedness as "a state of mental defect existing from birth, or from an early age, due to incomplete cerebral development, in consequence of which the person affected is unable to perform his duties as a member of society in the position of life to which he was born."

Whilst it is easy to cavil at any of these definitions the last is noteworthy because it definitely states the physical basis underlying the condition, and further recognizes that an individual may be regarded as feeble-minded in some walks of life and normal in others. It is this last fact which makes it so difficult to devise a wholly satisfactory or universally applicable definition of feeble-mindedness from the social aspect.

Sir James Crichton-Browne (3) defines a feeble-minded person as "one who by reason of arrested development or disease of the brain dating from birth or from some age short of maturity has his observing and reasoning faculties partially weakened, so that he is slow or unsteady in his mental operations, and falls short of ordinary standards of prudence, independence, and self-control."

It should be particularly noted that these definitions specifically mention arrested mental development—partial or complete—as the primary cause of the condition. The chief contribution which we have made to this subject is, as this memoir will prove, that we have shown that this degree of arrest can be estimated with a more reasonable amount of accuracy than heretofore.

Doll—in his "Clinical Studies of Feeble-Mindedness" (45), contributes an excellent discussion of the various criteria and definitions of mental deficiency. His conclusion is as follows:—"A threefold criterion must be employed, namely, *social inefficiency due to arrested mental development*."

In another place he remarks that "no one has ever satisfactorily demonstrated, except for some pathological types of feeble-mindedness, that the lack of mental development is due to incomplete cerebral development."

The first portion of this monograph is devoted to the consideration of this latter problem—the estimation of the completeness of cerebral development and its possible bearing on the diagnosis of mental defect.

Classifications of Mental Subnormality

Of the many classifications of mental subnormality which have hitherto been attempted, those which have found most favor are based on the psychological phenomena of mental age. That of Healy (4) is as follows:—

A. MENTAL DEFECTIVES.

1. Feeble-minded.

Idiots. Binet to 2 years.

Imbeciles. Binet, 2 to 7 years.

Morons. Binet, 7 to 12 years, unless there are special characteristics making for social success.

a. Generally defective.

b. Having special abilities which do not make for social success.

c. Having apparently, and sometimes actually, some special ability, such as good insight into his own defect, language ability, or motor ability, making for social success.

2. Mentally subnormal.

B. INDIVIDUALS DEFECTIVE IN SPECIAL AND LIMITED ABILITIES ONLY, OTHERWISE MENTALLY NORMAL.

1. Defective ability not interfering with social success.

2. Interfering with social success is some defective ability, such as:

a. Arithmetic.

b. Language.

c. Judgment, powers of mental analysis.

d. Self-control.

The recognition of the idiot and the imbecile presents no difficulties in diagnosis, and society is in no doubt as to their treatment—it simply segregates them.

It is the moron who constitutes the real difficulty for diagnosis and is at the same time the greatest social menace. As Goddard points out, the first point to be emphasized is that such people cannot be recognized from their physical appearance. The most dangerous group of mental defectives are those who are in no way different from the intelligent man, and not only in outward appearance, but in conversation and bearing, often pass for normal. They are thought to be simply untutored and it is supposed that training will bring them up to standard. But that such is not the case is testified to by the presence of hundreds of such cases in institutions for the feeble-minded, and by thousands of others who are not in such institutions, but who are recognized by those who know the feeble-minded, as being mentally deficient. It should further be noted that those forms of amentia, such as idiocy and imbecility, which are easily recognizable, even by a layman, constitute but a small percentage of the mentally subnormal. A very large number can only be diagnosed by experts specially trained in modern methods of neurological and psychological science.

Social Inefficiency

Pearson (5), in a special study dealing with the inadequacy of the present method of the recognition of mental deficiency, seems fully seized with the gravity and difficulty of the problem with which we are now confronted, for he says:—

“It appears to me that the term ‘mental defective’ ought to be replaced by some such term as ‘social inefficient.’ We are dealing with a class—at first recognized as school inefficients because they cannot take their place in the ordinary school community—who develop into ‘social inefficients.’ They are not necessarily mental deficient at all. They may have defective will control, but they may equally well have abnormal instincts, and one or other of these factors renders them incapable of taking their part in the common life of the community. . . . We have to see that we are really on the fringe of the biggest problem of the modern state—the question of social inefficiency. How are we to discover *a priori* from the school inefficients the social inefficients of adult life?”

Objects of the Present Work

The chief object of the present work is to demonstrate that it is possible to discover among school inefficients a large proportion of the potential social inefficients of adult life. For many years only the feeble-minded who were of the lowest grade of mentality, were recognized, but provision of new methods of child study has directed attention to the fact that there is a large number of people who are socially maladjusted, because of a degree of mental inefficiency which cannot be detected by casual observation. The development of standard age tests of mentality, such as the Binet-Simon Scale, has enabled us to distinguish still finer degrees of mental subnormality. Unfortunately, the immense popularization of mental tests has led, in regard to diagnosis, to an unwise emphasis on the importance of the demonstration of intellectual subnormality without a proper understanding of its social implications. We are now coming to recognize that intellectual retardation is not the sole factor in determining social success. In short, diagnosis has been attempted before scientific investigation has made possible the right interpretation of psychological examination data. One of the aims of this study is to put forth not only a more complete examination system, including the measurement of certain capacities important to social success which are not measured by the Binet, but also to give a better interpretation of results by delimiting the diagnostic sphere of each set of tests.

That it is necessary to obtain a clear clinical picture is shown by the results of the recent U. S. A. army examination of enlisted men.

The fact that such a high percentage of enlisted men was credited (by tests) with possessing a very low mental level seems to lead to one of two conclusions: either the tests fall far short as an adequate measure of intelligence or else a very low level of intelligence is quite consistent with social competency. If the first conclusion is correct, then there is an urgent need for extending the field of our psychological observations. If the second, the evidence of a fairly low level of intelligence cannot be accepted as diagnostic proof of feeble-mindedness. As regards the latter, we are loth to believe that the conditions of civilized life are anywhere so simple that, with a level of intelligence below that of many primitive races, individuals can function satisfactorily in society. We would rather conclude that it is the tests of the psychologists, as much as the intelligence of the subjects, that are at fault. In any case, whatever the conclusion, we are forced to demand a more adequate diagnostic examination before we can predict social inefficiency for the individual child. A realization of the inadequacy of any *single* method of approach to the problem, and also of the failure to evolve any satisfactory method of combining and interpreting the results of existing tests, has led the present authors to set forth a scheme which in their opinion contains the minimum requirements for clinical examination. In this system importance is attached to the demonstration of the physical, the educational, and psychological status, not only by the use of existing methods but by new diagnostic aids as well.

Plan of This Study

The plan of this monograph is, therefore, to set forth the various steps of our examination method, to discuss the standardization and validity of the diagnostic tests, and to show how their results may be synthesized and interpreted.

The definition of mental deficiency upon which our method depends is at the one time physical, psychological, and social. By anthropometric methods we attempt to demonstrate the somatic inferiority of the defective. In this part of our examination we make a systematic effort to determine the degree of cerebral development so far as it can be estimated by head measurements. This has been made possible by the establishment of norms of brain capacity for each age from six years to maturity—an investigation involving the measurement of over nine thousand subjects, including abnormal groups for comparative purposes. As this is entirely new work, the first part of the monograph is devoted to a discussion of the relation of brain capacity to mental development.

Part II deals with the physical, psychophysical, and psychological tests used in our method of examination. These tests and measurements

are so well known that any detailed description of them is superfluous; but with regard to the physical and psychophysical tests, it is necessary to justify their use in a system of mental examinations. Consequently, the correlation of mental and physical measurements is discussed in the first section.

In another section attention is devoted to the diagnostic implications that may be attached to a Binet age rating or in other words to the question of the proper interpretation of Binet test results. This involves a discussion of the standardization, value, and limitations of the Binet. A third section deals with the Porteus Tests and the proofs of their validity, correctness of standardization, and the question also of their interpretation.

Part III of the monograph deals with the method of synthesizing the results of the various examination methods, in order to present a clear clinical picture of the child.

New Material

The new material brought forward in this study comprises the following: (1.) A comparison of the brain capacities, by averages, for each age for various normal, subnormal, and delinquent groups, based on an examination of over 9,000 cases. (2.) The setting forth of percentile tables of brain capacity for males and females for each year of life during the educational period. These percentile tables admit of the comparison for diagnostic purposes of any individual child's capacity with the norms of his own age group. (3.) A summary of the results of the mental examination of 200 children in the extreme percentiles of brain capacity. (4.) An inquiry into the relation of psychophysical measurements to intelligence, based on the examination of 894 children by Binet, Porteus, and psychophysical tests. (5.) Correlation tables between Porteus test ages and grip, based on the examination of 1,248 cases. (6.) An examination of the standardization of the Binet and the Porteus Tests, based on results with 1,000 school children. (7.) A discussion of the application of the Porteus Tests to an additional group of 1,250 children, considering especially the factors of sex and social grade as affecting performance.

In all, the cases reported throughout this study number over 13,000. Although this number is large, our findings are in many respects not conclusive, and further research work is needed to round out this study.

The collection and treatment of the mass of this data constituted the work of the Laboratory of Educational and Physical Anthropology for the years 1917 and 1918. This Laboratory, established in the Anatomy Department of the University of Melbourne, was for this period under the joint direction of the authors of this study, and its work was carried on under a grant from the proprietors of the *Herald* newspaper, at Melbourne, with the assistance of the State Education Department of Victoria.

PART I

BRAIN CAPACITY AND INTELLIGENCE

Principles on which the Authors' Method Depends

The brain is the physical organ of mind. As mental development is conditioned by brain capacity, striking deviation from the normal in brain size will tend to be associated with mental abnormality. This assumption is not a mere theory but is in strict conformity with everything that Biology, Evolution, Embryology, and Medical Science generally, have to teach as to the relationship of "mind" to "brain matter." This principle is in no way disturbed by the facts to which we have in previous papers repeatedly directed attention, viz., that mental dullness, even to idiocy, may occur in either microcephalic or macrocephalic heads, as may also genius. But despite certain disturbing factors affecting the individual case, the general rule holds good that mental ability depends in the main on the number of fully developed neurones and their nerve connections, and, hence, as much on quantity as on quality. Fernald and Southard (10) in the introduction of the "Waverley Researches in the Pathology of Feeble-Mindedness," state the position both moderately and concisely when they sum up the mind and brain problem as "the less mind, the less brain, and vice versa, where 'less' is taken not too quantitatively." But the fact that what is often spoken of as quality of brain, viz.,—complexity of structure—normally means increased quantity, has not been sufficiently appreciated by either the expert or the layman. It is, therefore, desirable at the outset to survey briefly the evidence upon which this conclusion is based.

"The distinctiveness of man from his nearest allies," says Thomson (6), "depends on his power of building up ideas and of guiding his conduct by ideals." Man owes this unique position, as the head of the animal kingdom, entirely to the size of his brain. The human cerebrum is from two and a half to three times larger and heavier in man than in almost any other animal—living or extinct—and the cortical substance of his cerebral hemispheres is more richly convoluted than it is in any ape. This enlargement and increase of complexity involves all the lobes of the human brain except the olfactory.

If the brain of a primitive mammal be viewed from its lateral aspect it will be found that the major part is composed of the "smell brain" or rhinencephalon. The remaining portion—the neopallium—comprises an

auditory or acoustic centre, an optic or visual centre, a sensori-motor centre, and a controlling centre. These last are the primary sensory areas of the neopallium. The brain of such a primitive mammal is, therefore, little more than a nerve mechanism by means of which the living organism is brought into contact with the world around it and with the natural phenomena of that world, such as light, sound, temperature, odors, and so on.

In the process of evolution there have been evolved around and between the primary sensory areas of the neopallium, secondary or association zones, which attain their greatest size and highest development in the human brain and give to it its great mass. It is within these secondary, or association, zones that the mental processes of memory, reason, judgment, and other manifestations of intellectual phenomena—as apart from the purely physical functions of life—arise, though how, and in what way they are carried on, is unknown.

The Evidence of Anthropology

Anthropology affords the same general and unmistakable evidence of mental development being governed by size of brain. The cranial capacity of anthropoids, primitive man, and modern man is accurately known and is quoted in every text-book. From anthropology alone, even though there were no other collateral lines of evidence, there is abundant proof of the fact that increasing complexity of mental function necessitates an increasingly large brain and a correspondingly large skull for its accommodation.

The Evidence of Brain Weight

That there would appear to be an appreciable correlation between brain weight and general racial "intelligence" the following figures (7) show:—

	Grammes
Australian aboriginal, low intelligence.....	1185
Negro	1244
Malay	1266
Sandwich Islander	1303
Chinese	1332
Caucasian, high intelligence	1335

That the general level of intelligence is higher in the adult than in the child is an obvious fact, which is fully reflected by the difference in the brain weights. Boyd (8) gives the following:—

	Grammes
From 4 to 7 years of age	1138
From 7 to 14 years of age	1301
From 14 to 20 years of age	1374

Pfister (9), from an examination of 156 cases, obtained the following brain weights during infancy and childhood:—

	Grammes
End of the first month	455.2
End of the second month	458.2
End of the third month	515.7
Fourth and fifth months	573.4
Sixth and seventh months	734.0
Eighth and ninth months	752.2
Tenth and twelfth months	832.3
Second year	977.3
Third and fourth years	1150.4
Fifth to eighth year	1202.0
Ninth to fourteenth year	1279.9

Matiegka (11) has examined the brain weights of a considerable number of individuals drawn from different classes of life and concludes therefrom that it is clear that high intelligence is causally associated with an increase in brain weight.

Spitzka (12), in 1906, collected the records of the brain weights of 100 distinguished men and found the average weight to be 1469.95 grammes, or fully 100 grammes above the average for Europeans. He further showed that the senile decrease in weight is delayed about 10 years in the “distinguished” as compared with the “ordinary” series.

The Evidence of Crania

Turning next to the evidence to be gleaned from the many researches to which the skull, or brain-containing case, has been submitted, it is instructive to study a series of median sagittal sections through the crania of such animals as the deer, baboon, and man—animals obviously widely separated from each other in degrees of mentality. Such a series as is here referred to may be seen in Wiedersheim’s “The Structure of Man” (13). It will be at once obvious that the most intelligent of the three animals selected—man—has not only the largest brain, but has also the largest brain case in which to contain that brain.

If diagraphic tracings of the median contour lines of the crania of— from the point of view of general intelligence—such widely separated animals as the anthropoid ape, *Pithecanthropus erectus*, the Piltdown man, the Neandertal man, and *Homo sapiens* be examined—and every text-book furnishes examples—the same general truth is at once evident. A higher intelligence demands a larger brain, and as “in some mysterious fashion, the growth of the brain governs that of the future skull” (14), —the larger brain necessitates a larger skull.

The Evidence of Pathology

In the pathological condition known as microcephalic idiocy, the idiocy results simply because the amount of brain matter is so much reduced in quantity as to render the individual incapable of "building up ideas and of guiding his conduct by ideals." In such conditions the amount of cerebral cortex necessary for the performance of the physical functions of life is present, but the association centres are so much reduced in area as to result in idiocy.

Bardeleben's "Handbuch der Anatomie des Menschen" (15) contains many examples of the brain weights of microcephalic idiots ranging in the male, from 289 grammes to 559 grammes, all in adults. In all these cases actual idiocy was present and is solely attributable to actual deficiency of brain substance. According to Hess, a brain weight of 74 grammes is the lowest with which even passable intelligence may be associated. Elliot Smith (16) is of opinion "that a brain must reach a weight of 950 grammes (or about 1,000cc. in volume) before it can become the seat of even a low form of human intelligence." Keith (17) apparently agrees with Elliot Smith, for he says "with brains of a smaller size than 930cc. we can scarcely expect a human intelligence."

Summary of the Evidence

From even the foregoing abbreviated summary of the evidence it is indisputable that mentality depends on brain matter and that there is a definite relation between the two. The principle, upon which our work is based, that as mental development is conditioned by brain capacity striking deviation from the normal in brain size will tend to be associated with mental abnormality, would appear not only to be correct, but to be a sound principle upon which to proceed in the diagnosis of mental subnormality.

Nature's Methods of Adapting the Size of the Brain to Higher Intelligence

It is of great interest, both from a general standpoint, as also from the objective of the present work, to study the ingenious methods adopted by nature to evolve a sufficiently large brain for the high intellectual requirements of modern man. These changes have necessitated a long and gradual evolution spread over long periods of geological time and a large number of animal forms. There are at least five ways in which the human brain has been modified, adapted, and increased in size, in order to equip it for the special intellectual purposes of man. These are as follows:—

1. By an actual increase in size.
2. By the partial suppression of certain animal senses, such as that of smell, and to a lesser extent, that of sight.
3. By the addition of the neopallium or brain mantle.
4. By infolding of the cerebral cortex.
5. By lamination of the cerebral cortex, and the addition thereto of a controlling or supra-granular layer.

Of these methods of natural adaptation of the brain to a higher intelligence, only one—the last—can here be considered. That one, on account of its very great social significance and its important relation to the present work, must, however, be considered in detail.

Lamination of the Cerebral Cortex

During the last few years some important histological investigations have been carried out on the cerebral cortex by Campbell, Elliot Smith, Bolton, Watson, Bevan Lewis, Mott, Vogt, Brodman, Cajal, Flechsig, and others.

It has long been known that the grey cerebral cortex is composed, histologically, of a laminated arrangement of variously shaped nerve cells, with their axons and dendrites, embedded in neuroglia. In that part of the general somaesthetic area of the human brain which is known as the posterior central gyrus eight histological layers are distinguishable, details of which may be found in every text-book. Whilst it is not necessary to describe these layers here, it is of considerable importance for our work that they should be collated—as regards nomenclature and position—with more recent work of Bolton (18), Watson (19) and Mott, whose investigations may be said to have revolutionized our conceptions of the physiological workings of the human cortex. This may be done as follows:—

HISTOLOGICAL	BOLTON AND MOTT	WATSON
Layer No. 1	Outer fibre lamina or molecular layer.	
Layer No. 2	Outer cell lamina.	Supra-granular layer
Layer No. 3		
Layer No. 4		
Layer No. 5	Middle cell lamina of granules.	Granular layer
Layer No. 6	Middle fibre lamina. The "inner Line of Baillarger."	Infra-granular layer
Layer No. 7		
Layer No. 8		
	Inner cell lamina of polymorphic cells.	

Development of the Layers of the Cerebral Cortex

In the human foetus of four months, lamination of the cerebral cortex is not only not present, but has not even commenced. At this period of life the cerebral cortex consists of a superficial indifferent layer, and a deeper layer of undifferentiated neuroblasts, and the total thickness of the cortex is, at this period, less than half the normal adult depth. Developmentally, the inner cell lamina of polymorphic cells—that is, the deepest of the cortical layers—is the first to appear, and by the sixth month of foetal life has attained a depth of about three-fourths of the adult depth and thereafter undergoes a slow further development until after birth. In a child six weeks old it has attained a depth of 82% of its total, that is, it has a depth at six weeks which is within 18% of its total adult normal depth.

In the sixth month of foetal life the middle cell lamina of granules makes its appearance. It develops rapidly, and at birth has attained a depth which is nearly 75% of its total adult thickness.

The outer cell lamina or the supra-granular layer is not only the last of the cortical laminae to make its appearance, but is also the slowest to attain its adult condition. In a foetus of six months it has only attained 25% of its total adult depth. It increases slowly and at birth has about doubled itself, that is, it is still little more than one-half or 50% of its total adult depth.

The foregoing account of the ontogenetic development of the human cerebral cortex by Bolton (18) is confirmed by G. A. Watson (19) from the phylogenetic aspect. He says:—

“Regarded from the developmental aspect—ontogenetic and phylogenetic—the facts support the thesis that the neopallium of the mammalian cerebral cortex is built up primarily on an infra-granular basis, that is, the infra-granular portion is the earliest to appear in the process of development, very quickly reaches maturity, and in the adult, especially if average size of component nerve cells is taken into consideration, presents remarkably little difference in absolute depth in one of the lowest mammals and in the highest.”

The granular layer may be said to be the next addition to the cortex. Ontogenetically it appears shortly after the infra-granular portion of the cortex, and it reaches its maximum development in depth and definiteness in the projection spheres of the cerebrum.

The last layer of the cortex to appear ontogenetically is the supra-granular or pyramidal layer. It is the slowest of all the layers to reach maturity. It is scarcely existent at all in certain regions in some, if not all, of the lowest mammals, and even at its best in the latter it reaches

but a slight absolute depth as compared with its depth in practically every region of the neopallium in the human subject.

These general conclusions are still further confirmed by Watson from his Comparative Anatomy studies. He finds that in the Insectivora the supra-granular layer is in a rudimentary condition, though the deeper layers of the cortex cerebri approximate in depth to that of these layers in the normal human adult. Further, the supra-granular layer is better developed in the Rodents than in the Insectivora. It is again better developed in the Ungulates and in the Carnivores than in the Rodents, and is strikingly more developed in the Primates than in the Carnivores.

It is, therefore, certain that Comparative Anatomy and Embryology, Phylogeny and Ontogeny, all force upon us the conclusion, to which Watson himself has come, that the supra-granular layer is "functionally correlated with the educability and general intelligence which appear in an increasing degree during the ascent of the Mammalian scale."

Functions of the Infra-Granular Layer of the Cerebral Cortex

Regarded next from the standpoint of function, the work of Watson and Bolton is equally striking and equally important for the correct appreciation of the results of our work. Watson, it will be remembered, divides the cerebral cortex into three main layers, which are from within outwards, and in a chronological order of development, as follows:—

The infra-granular layer.

The granular layer.

The supra-granular layer.

"The infra-granular portion of the cortex (omitting the constituent cells which possess motor or analogous functions) is concerned especially with the associations necessary for the performance of the instinctive activities, that is, all those which are innate or require for their fulfilment no experience or education. These form the basis of many complex actions necessary for the preservation of the individual and the species, such as the seeking of appropriate shelter and protection, the hunting of food—each after his own kind—and the quest of the opposite sex." (Watson, 19.)

"The infra-granular layer of the human cerebral cortex is its oldest layer both phylogenetically and ontogenetically. It is the first to appear and most quickly attains maturity. It subserves the lower voluntary and instinctive activities of the animal economy and thus forms a lower level basis for the carrying on of cerebral function. The layer is increased in thickness in cases of high-grade amentia and of chronic insanity with moderate dementia. A considerable decrease, on the other hand, exists in more marked aments (whether foetuses or infants, or idiots and

imbeciles) and in gross demented who are unable to carry on the ordinary animal functions, such as attending to their own wants." (Bolton, 18)

Functions of the Supra-Granular Layer of the Cerebral Cortex

"The supra-granular layer of the cerebral cortex, which, relatively to the infra-granular layer, is so poorly developed at birth, is slow in reaching maturity, and is, even at its best, in certain lower mammals, such as the Insectivora, only of an insignificant absolute depth, subserves the higher associations, the capacity for which is shown by the educability of the animal. It has, therefore, to do with all those activities which it is obvious that the animal has acquired (or perfected) by individual experience, and with all the possible modifications of behaviour which may arise in relation to some novel situation, hence with what is usually described as indicating intelligent as apart from instinctive acts, the former being not merely accompanied but controlled by consciousness." (Watson, 19.)

"The supra-granular layer is the most prominent feature of the human cortex and constitutes a 'higher level' basis for the carrying on of the cerebral functions. It is the last layer of the cortex to be evolved, the last to commence to develop, the last to attain maturity, and consequently the first to undergo retrogression. From the evolutionary standpoint, having been recently added, it is in a state of 'instability.' It is the only cell layer of the cerebral cortex which varies definitely in measureable depth in 'normal' brains. It is underdeveloped to different degrees, according to the mental capacity of the individual in persons exhibiting various grades of mental subevolution, and it undergoes degrees of retrogression which correspond to the amount of dementia existing in cases which permanently suffer from diminution or loss of their mental powers." (Bolton, 18.)

Estimation on the Living Subject of the Degree of Cerebral Development Attained

The shape and size of the head depend on the shape and size of the brain, and the strength of the muscles which arise from the skull. Of these two factors, brain growth is by far the more important, and muscular action only exercises a minor influence. In an ordinary normal human brain there should be some 9,000 million neurones. Assuming that only one-third of these belong to the supra-granular layer, it should be obvious that if they fail to develop normally, or their axons to myelinate, the individual will not only have a much smaller brain, but will also have a smaller head, which can be detected in life, and its significance, if any, determined by mental and other tests. It should also be

clear that in extreme cases the individual cannot possess a normal intelligence, but will have the instincts of the brute from his infra-granular layer, with about as much control over those animal instincts as any other animal with an insufficient supra-granular layer.

The following table, based on the researches of Bolton, Watson and Mott for the foetus, and on our own observations for the child, shows the ontogenetic development of the supra-granular and infra-granular layers of the cerebral cortex:—

Table No. 1

Period of Life	Infragranular Layer.	Supragranular Layer.	Volume of Brain.
4th mo. foetus.	Undifferentiated neuroblasts.	Superficial indifferent cells.	
6th mo. foetus.	75% adult thickness.	25% adult thickness.	
Birth.	Remains almost stationary.	50% adult thickness.	25% total volume.
6 weeks old.	82% adult thickness.	60% adult thickness.	
1st Birthday.			63.7% total volume.
2nd Birthday.			72.5% total volume.
4th Birthday.			80.0% total volume.
13th Birthday.			91.1% total volume.

This table makes it clear that post-natal brain development is chiefly associated with supra-granular cell growth. If, therefore, the total volume of the brain is much below what our figures show it should be at any period of life, then there is the justifiable inference that it is the supra-granular layer which is lagging behind in development. If this inference be confirmed by the other avenues of approach of our method the diagnosis becomes certain, and the remarks of Bolton and Watson, already quoted, prove the great social significance of the observation.

Summary of Cortical Development

The facts given in the foregoing sections, because of their importance, may be again summarized as follows:

The most important portion of the cerebral cortex is the supra-granular layer. It is the layer which most distinguishes the human from the animal cortex. It undergoes degenerative changes in certain types of dementia, and is imperfectly developed in cases of feeble-mindedness. It subserves the higher thought processes and is, therefore, the layer through which education works. It is the layer which is last developed,

having at birth attained only fifty per cent. of its ultimate adult development.

The granular layer is thought to subserve the sensory functions, because in it the sensory nerve cells have their endings, and because its greatest development occurs in those areas of the brain to which are ascribed the sensory functions. At birth it has attained seventy-five per cent. of its ultimate adult thickness. Through this layer and its nerve connections the organs of sense are able to serve as the feeding inlets from the outside world to the mind. Hence the development of the supra-granular layer is largely dependent upon the activity of the nerve cells of the granular layer. If this stimulation is cut off in any direction, as for instance in blindness or deafness, a diminished brain growth results—(See average capacity of deaf and dumb boys, Figure 1). The granular layer itself, however, probably attains its full development shortly after birth.

The infra-granular layer is relatively and absolutely as well developed in the higher animals as in man, and is developed equally well in the feeble-minded as in the normal individual. It is supposed, therefore, to subserve the instinctive activities, such as the self-protective and sexual. Shortly after birth it has eighty-two per cent. of its ultimate adult development in depth. Judgment, common sense, reason, as evidenced in behavior, in a word social efficiency, are dependent on the control of the activities of the infra-granular layer by the supra-granular.

It is evident from these facts that post-natal brain development is mainly concerned with the development of the supra-granular layer. Hence, when we measure the growing brain throughout childhood we are obtaining an estimate, approximate, it is true, of the development of this all-important layer of nerve cells with its nerve connections. In all probability the important brain growth which normally occurs after puberty is wholly concerned with the completion of the development of the supra-granular layer. In a premature arrest of its development lies the physical basis of the great majority of cases of pauperism, vice, crime, and other forms of social inefficiency. As this pubescent growth is connected with control of instincts, rather than with learning capacity, ordinary mental tests may fail to show the existent defect. Hence, the importance of early recognition of the potential abnormal case and the following up of his development from infancy to maturity.

Correlation of Brain Weight with Individual Intelligence

Whilst it is incontestably true that "intelligence" is correlated with "brain," accumulating data prove beyond question that as applied to individuals, the weight of the brain alone is an untrustworthy index of relative

intelligence. This need cause no surprise when it is remembered:—

1. That the weight of the human brain is not uniform throughout life.
2. That the human brain is composed of functional nerve elements—neurones—embedded in non-functional supporting tissue—neuroglia.
3. That brain weight is profoundly modified by the presence or absence of post-mortem fluids.
4. That the measure of intelligence is not always accurate.

From the evidence of human anatomy it is known that the human brain is absolutely heavier between 14 and 20 years of age than at any other period of life, and that at the age of 80 years it has lost about 90 grammes, that is, about one-fifteenth of its total weight—a loss which chiefly affects the supra-granular layer of the cerebral cortex. Hence the gradual loss of mental power in the aged.

As regards modification in brain weight induced by the presence or absence of post-mortem fluids Pfister (9) found that a strong hyperaemia of the brain might raise its weight 7.5% above the normal, whilst a marked anaemia might similarly lower the weight, thus giving a range of 15%.

Correlation of Brain Capacity with Individual Intelligence

As it is clearly impossible to weigh the brain on the living subject, the mathematician has come to the assistance of the anatomist and has devised formulae for the determination of the cubic capacity of the brain from the diametral or circumferential measurements of the living head. The estimation of the brain capacity of the living subject and its correlation with the reputed intelligence of the individual is, however, an even more complex problem than the correlation of brain weight with intelligence, and bristles with difficulties and possible sources of error. Amongst these at least may be mentioned:—

1. The nature and contents of the skull.
2. The construction of the brain.
3. Biological and social factors.
4. The degree of accuracy of the mathematical formula employed.
5. The possible presence of pathological conditions affecting size.

Whilst it is certain that under normal conditions head size must, to some extent at least, be indicative of brain size, it must not be forgotten that the brain-containing skull contains other structures besides neurones. These additional structures comprise meninges or brain coverings, blood vessels and nerves, cerebro-spinal fluid, and neuroglia. On the exterior of the skull there are, in addition, the soft parts of the scalp, whilst lastly,

there is the thickness of the skull itself. It necessarily follows that in all calliper measurements of the living head the measurements are "over all" ones, and allowance has to be made for the thickness of both scalp and skull, which varies within a fairly wide range which, however, is fairly accurately known, as are also the relative proportions of structures within the skull. Estimations of the cubic capacity of brain on the living subject are, therefore, liable to a not inconsiderable margin of error, and hence the conflicting results of the many researches which have been undertaken to determine the correlation between brain capacity and intelligence. It need hardly be added that the present authors do not make use of head measurement alone for the purpose of detecting intelligence, but merely as an ancillary method of diagnosis.

It has already been pointed out that the normal human brain is composed of some 9,000 million neurones embedded in a non-nervous supporting substance termed neuroglia. An excess of neuroglia may, therefore, result in a large "unintelligent" brain and head, whilst conversely a diminished amount of neuroglia may give—though apparently less frequently—a small "intelligent" brain and head. This complication is, therefore, common to both brain weight and brain capacity, when correlated with the reputed intelligence.

It has already been seen that "intelligence" depends on the degree of the development of the brain, and that in human races and social classes the correlation between the two is actually demonstrable, and is in accordance with the laws of Nature. Though what holds good for the race or class should also theoretically be true for the individual, the correlation is often obscured by heredity, habits, disposition, disease, opportunity, and good or bad social influences. No matter how accurate the estimation of brain capacity it may be of less importance than these biological and social factors which so greatly affect mental development.

As it is clearly impossible to devise an error-proof method of estimating the cubic capacity of brain on the living subject, it only remains to select a procedure which shall be most free from such error. Of the methods which have so far been devised as the physical basis of the brain calculation all fall into one or other of two categories, namely, those which employ circumferential head measurements, and those which use diametral ones. The investigations of Anderson (21), Berry and Buchner (22), and others, have conclusively proved diametral head measurements to be distinctly preferable, and Lee's formula No. 14, (23), to be the most accurate for the calculation of the cubic capacity of brain from the head measurements. All this notwithstanding, it must be distinctly understood that even these methods are not free from error. They are, however, the only existing ones which are free from gross error.

It is indisputable that the occurrence of gross pathological lesions may occasionally so affect the size of the brain and the head, that the brain capacity measurements have no relation to the intelligence of the individual. The detection of these pathological conditions is wholly a medical problem with which we are not now concerned.

Defective Brains

Though the amount of work which has been done on the anatomy and histology of the brains of feeble-minded is not large, there is ample confirmation from many sources of the fact that the brains of defectives are characterized by a quantitative deficiency of brain cells in the cortical layers. Tredgold (2) says: "As compared with the nerve cells of the healthy brain, those of the ament are characterized by the following conditions: 1, Numerical deficiency; 2, irregular arrangement; 3, imperfect development of individual cells; and on the whole it may be stated that the amount of change discoverable by the microscope is directly proportionate to the degree of mental deficiency present during life."

Referring to numerical deficiency of cells, he says further: "In many cases this paucity of cells produces a decrease in the thickness of the cortical gray matter, which is obvious to the naked eye."

The earlier work of Hammarberg (25) on the brain anatomy of the feeble-minded gives additional support to the view that mental defect is in all cases connected with defective cells in the cortex, the arrest of development occurring either at an ante-natal or early neo-natal stage, so that a comparatively small number of cells reach a normal development. Tredgold also states, that "the essential basis of amentia is an imperfect or arrested development of the cerebral neurones," and that the number and complexity of the nerve processes, particularly those forming the association systems, are intimately connected with the degree and complexity of cerebral activity. He refers to the opinion of Kaes, that the increase of fibers tends to go on to the middle period of life.

Recent work by Ellis (46) has an interesting bearing on the question of the quantitative deficiency of cells in the cortex of the brains of feeble-minded individuals. His investigation proves that there is a distinct numerical deficiency of Purkinje cells in the cerebella of low-grade defectives, particularly in those in whom motor co-ordination is defective. He remarks, "Here, then, we have an anatomical deficiency as a basis of the observed deficiency in motor co-ordination." He shows also that many of the cells counted were imperfectly developed. This investigator adds his testimony to that of the authors we have already quoted, that in the cerebral cortex also "there is ordinarily a distinct deficiency in

cells in cases of amentia." He concludes from this evidence, that in idiocy and imbecility we may expect to find the whole brain defective, rather than the frontal lobes only.

It is therefore evident that the effect of this lack of development of nerve cells and processes should normally be reflected in head size. Both brain weight and brain size may, however, be seriously affected by a neuroglial over-growth. According to Wilmarth (26), twenty-five per cent. of the cases studied by him show sclerosis in one form or another. Hunter (20), says, "Occasionally in cases of hypertrophy of the brain (enlargement is generally due to an increase in the neuroglia) the brain may consequently exceed the normal, both in size and in weight. Hewat (20), writing of the epileptic child, refers also to the neuroglial deficiency of cells, to the irregular arrangement and imperfect development, and to a neuroglial overgrowth as being characteristic appearances. Southard (10), in a portion of the extremely valuable "Waverley Researches," quotes Mierzejewski's opinion that the basis of every anatomical lesion in the idiot's brain is a developmental deficiency in the nerve tissue, and that there can be no question of any true arrest of development without this morphological and histological basis in the entire brain. The latter refers also to cases of a disproportionate development of white and gray matter, in which the arrest of development on the part of the latter is of slighter degree as compared with the deficiency of the white matter.

In a preliminary report by Porteus* of his study of the cephalometry of feeble-minded, a study founded on the method and tables described in Part I of this monograph—the results with the first 50 cases are given. The distribution by percentiles of these subjects is shown in Fig. I. It will be seen that 50 per cent. had brain capacities outside the limits of the 10 and 90 percentiles, whilst only 30 per cent. were found in the six deciles between the 80 and 20 percentiles.

Summary of the Scientific Principles upon Which the Authors' Use of Brain Capacity in the Diagnosis of Mental Subnormality Is Based

The brain is the physical instrument of mind.

Arrested brain development, whether partial or complete, results in some form of mental subnormality.

As head growth is almost entirely governed by brain growth, striking deviation from the normal in head size will tend to be associated with mental abnormality.

The supra-granular layer of the cerebral cortex is the layer of educability and controls the instinctive animal cells of the infra-granular layer.

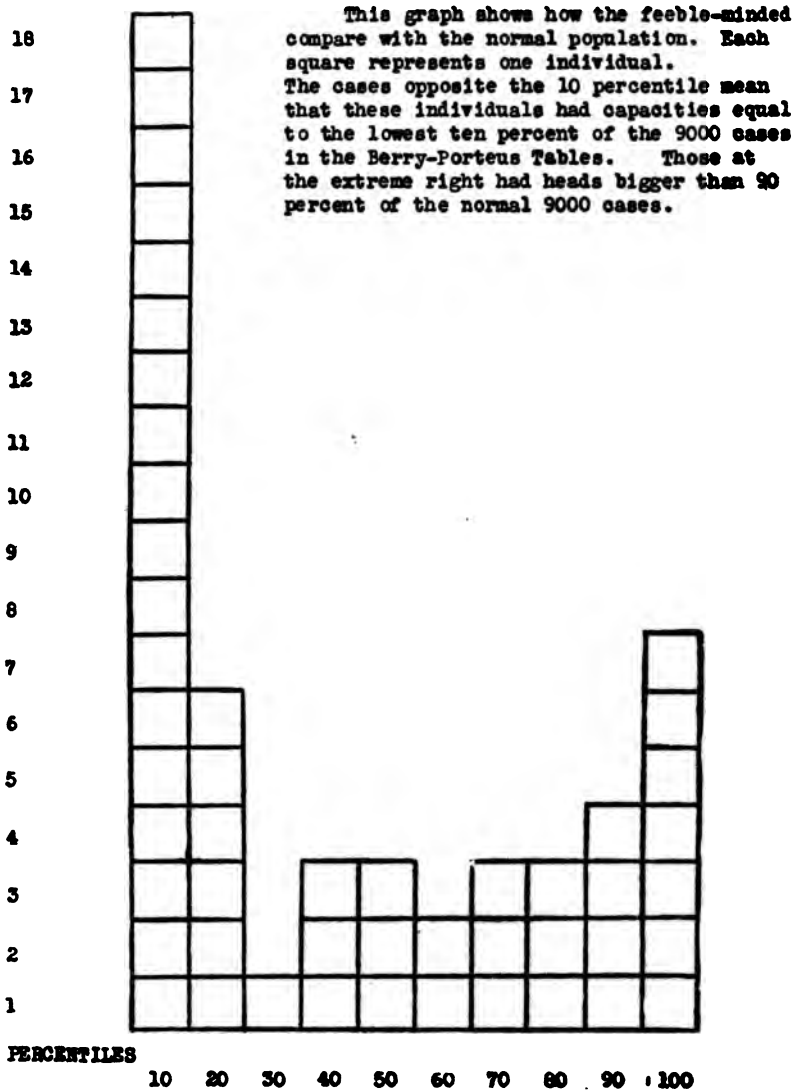
*"Cephalometry of Feeble-minded," by S. D. Porteus. Reprint from *Training School Bulletin*, June, 1919.

Figure 1

BRAIN CAPACITY OF FEEBLE-MINDED.

No of
Cases

DISTRIBUTION OF PERCENTILES.



Being an evolutionary recent addition to the cortex of the neopallium, the supra-granular layer frequently fails, from a variety of causes, to attain full development in the individual. Such an individual approaches, therefore, in his behaviour more nearly to the animal type of "instinct," than to the human type of "reason."

Within reasonable limits the state of development of the cortical layers of the brain can be detected on the living subject.

Mental deficiency, potential social inefficiency, and to a lesser extent, even mental efficiency, can be diagnosed in childhood to the lasting benefit of the community.

THE BRAIN

First Object of the Investigation

Whilst it has been made abundantly clear that mental development is conditioned by brain capacity, and that striking deviation from the normal must tend to be associated with mental abnormality, it is clearly impossible to determine the frontiers of abnormality until the normal be known. As the cubic capacity of brain of a normal boy or girl, at the different ages of their educational career, was quite unknown, we were compelled, at the very outset of our investigation, to undertake an enquiry of very considerable magnitude, which had as its first and immediate object, the determination of the amount of cubic capacity of brain which the average normal boy or girl should possess at every year of educational life.

Method of Carrying Out the Investigation

At the instigation of one of us (Berry) a preliminary enquiry was first carried out by Dr. J. H. Anderson (21) as to the best method of determining the cubic capacity of brain on the living subject. In accordance with his results, we adopted the diametral measurements of head length, head breadth, and head height for the head measurements, and Lee's formula No. 14 (23), for the calculation of the brain capacity. To reduce error to a minimum, the whole of the field work was carried out by one person only, who was first specially trained in the laboratory.

Method of Recording the Head Measurements

The head measurements were recorded in strict accordance with the instructions laid down by the British Association for Advancement of Science* (24) as follows:—

*A description of methods and instruments which differ somewhat from those employed by us are described by Dr. Ales Hrdlicka, in the *Journal of Physical Anthropology*, for July-September, 1919.

1. MAXIMUM HEAD LENGTH. Measured from the most prominent point of the glabella to the most distant point in the middle line on the back of the head, known as the occipital point. The observer stands on the left side of the person being measured and the fixed point of the callipers is first applied to the glabella, and held there by the fingers of the left hand, while the other point is moved over the mid-line of the back of the head (occiput). Care must be taken to observe that the fixed point has not been moved off the glabella during the measurement, and that the points of the callipers have not been deflected from the median vertical plane. The pressure of the points of the callipers on the head should be as much as can be comfortably borne by the person under examination. This diameter is recorded by means of Flower's callipers.

= L

2. MAXIMUM HEAD BREADTH. Measured wherever it can be found above the plane of the ear holes. The callipers should be held in a vertical transverse plane and moved about until the maximum diameter is ascertained, the observer being careful to keep the points of the callipers exactly opposite to one another. The pressure of the points on the head should be as much as can be comfortably borne by the person under examination. This diameter is recorded by means of Flower's callipers.

= B

3. HEAD HEIGHT. Measure from the mid-points of the ear holes to the highest point of the cranium measured in a vertical plane when the eyes are directed to the horizon. This diameter is measured by means of Gray's, or other radiometer.

= M₂

*In Portman 1919: 6
called bregmatic*

Precautions to be Observed in Recording Head Measurements

Although the method of recording the head measurements appears so simple that it may be acquired by any layman in a few minutes, there are certain pitfalls against which the tyro should be warned. Amongst these is the pressure to be employed. If the pressure of the points of the callipers on the individual's head be insufficient, too high a reading will be obtained, and if it be unduly severe, too low a reading will be recorded. As stated in the official instructions just quoted, the pressure "should be as much as can comfortably be borne by the person under examination." If there be any doubt about the measurements, the reading should be recorded three times and the average taken as the correct one. With these simple precautions two observers should not differ from each other by more than one millimeter for head lengths and head breadths.

As regards height, it is absolutely essential for the correct procedure to be employed. It is the most important of the diameters for the future calculation of the cubic capacity of brain, and errors in its reading may

seriously affect the calculations. The individual should be directed to look straight ahead of him so that his line of sight is parallel with the ground. If this be not done, the head will tend to fall forward or backward, and sources of error are immediately introduced. As regards the pressure to be employed it must be firm without hurting or dragging on the ear-holes. In the introduction of the ear-rods of the radiometer into the ear-holes, care must be taken not to force the instrument into the latter, otherwise there is a risk of damaging the delicate ear-drums or membranae tympani. This source of danger may, however, be eliminated by getting the individual himself to introduce the ear-rods into the ear-holes while the observer supports the instrument. Lastly must be remembered the possibility of a careless reading of the instrument.

Even with these precautions there will still remain slight "personal" errors, which, in our judgment, will never be entirely eliminated until head measuring instruments are devised with a pressure-gauging apparatus by means of which the pressure employed can be accurately recorded, and reproduced at any time by any other observer. This is particularly important if yearly measurements are to be recorded on the same individual, for, as will be seen later, the annual increments in growth of head length, head breadth, and head height, are frequently less than the amount of the "personal error."

It would be well to have all the observations recorded by one specially trained individual.

Mathematical Formula for the Calculation of the Brain Capacity

For the calculation of the cubic capacity of brain from the diametral measurements of head length, breadth, and height, we have, for the reasons already set forth, employed Lee's formula No. 14, which is as follows:

Male. Brain cc. = .000337 (L-11 mm.) (B-11 mm.) (H-11 mm.) + 406.01

Female. Brain cc. = .0004 (L-11 mm.) (B-11 mm.) (H-11 mm.) + 206.6

The reasons why Miss Lee employs a different formula for males and females is because "the ratio of male to female skull capacity would thus be 1.13, corresponding well with the ratio of brain weights, 1.12, as determined by Reid and Peacock."

Notwithstanding that Miss Lee claims that her formula gives the cubic capacity of the skull to within "a mean error of 3 to 4 per cent.," we did not adopt it until the method had been thoroughly investigated and tested. Whilst agreeing that it is the most accurate method available we are of opinion that its accuracy is not as great for the living subject as for the dried skull, nor is it necessary to employ a different formula for females. As will be seen later, the male formula suffices for both sexes.

From the recorded measurements of length, breadth, and height, Miss Lee subtracts 11 mm., which in her judgment represents the allowance to be deducted for the average thickness of scalp and skull.

Neither Miss Lee's method nor any other method can make any allowance for the varying ratios of brain and cerebro-spinal fluid, or for those of neurone and neuroglia. These subtle distinctions will be only partially, or more frequently not at all, detected by head measurement, but their influence will almost certainly be revealed by the subsequent psychological examination. Fortunately the ratio of brain to cerebro-spinal fluid is not very variable during the growing period of life, when measurements will have a value; but with advancing age, and co-incident with the subinvolution of the brain, which occurs in the aged, the fluid may attain 19.5 per cent. of the skull contents.

The actual calculations of the brain capacity from the formula, though somewhat long, can readily be worked out by simple arithmetic, and in very few seconds by a calculating machine.

Material for the Determination of the Cubic Capacity of Brain

Of males we have examined 6,700, as follows:—

NORMAL CASES.

1. Victorian State School boys between the sixth and fifteenth birthdays	4,177
2. Victorian Public School boys and Melbourne University students between the sixth and thirtieth birthdays....	2,104
3. Adult inmates of the Melbourne Benevolent Asylum for the Aged and Infirm	217

ABNORMAL CASES.

4. Bell St. Special School (Melbourne) for the Mentally Deficient	39
5. Montague Special School (Melbourne) for the Mentally Deficient	21
6. Victorian Deaf and Dumb Institute	53
7. Castlemaine Reformatory for Indeterminate Sentence Criminals	25

PRIMITIVE RACE.

8. Australian Aboriginal Natives	64
--	----

TOTAL 6,700

Of the females we have examined 2,717 Victorian Public School girls

and Melbourne University women students.

The detailed results of these 9,417 cases either are to be found in the Laboratory of the Anatomy Department of the University of Melbourne, or have been returned to the schools concerned.

Analysis of the Material

As regards the males, the three groups of "normal" cases represent three distinct types or grades of the population.

The "abnormal" cases also comprise three distinct groups, the admittedly mentally defective, the deaf and dumb, and the criminal. They were primarily selected as a control group, but subsequently proved to have a special interest of their own. The inclusion of the representatives of a primitive race, like the Australian Aboriginal of the Northern Territory of Australia, furnished us with a useful evolutionary "control," and has added to the general scientific interest of the work.

It will probably occur to the reader that if the principle upon which this work is based be really correct, it should be demonstrable in the widely separated "class" groups which are here dealt with; and that conversely, if it be not demonstrable, the whole of the hypothesis on which we are working falls to the ground. This is legitimate criticism, and is strikingly answered by Fig. 2, which illustrates the generalized results for the various normal and abnormal male classes of our investigation.

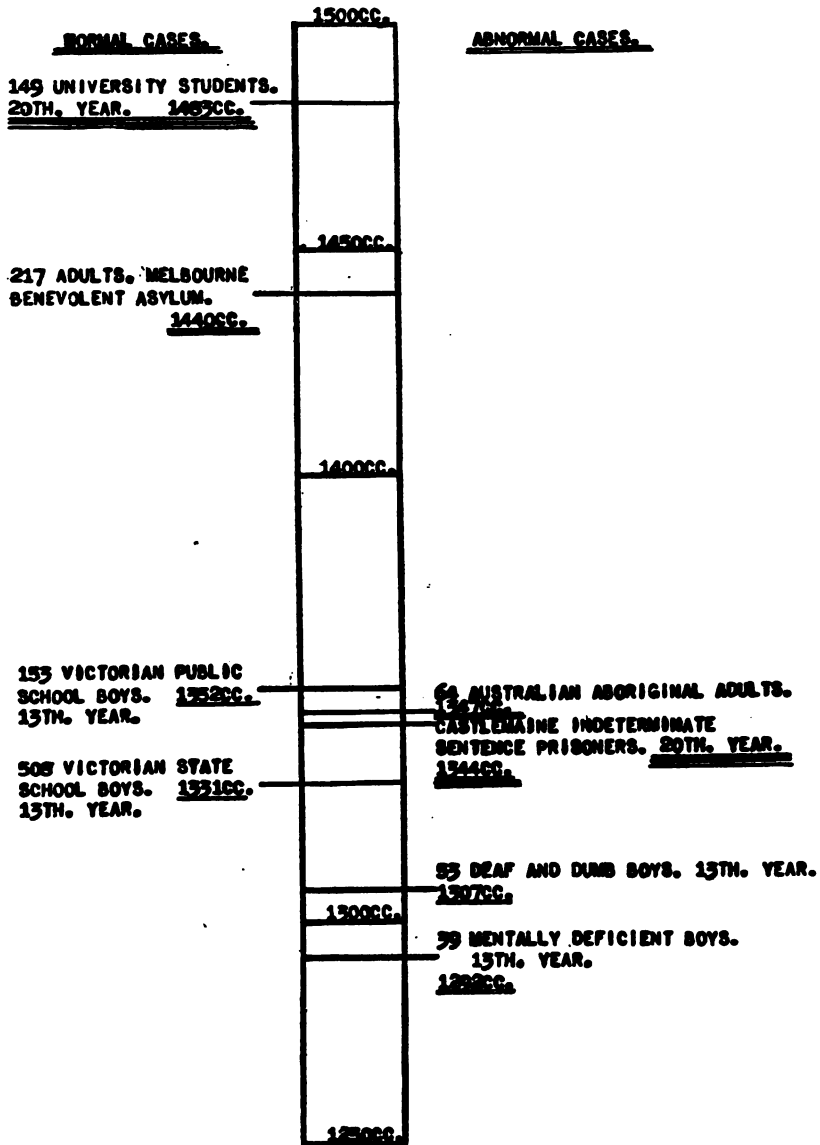
It is impossible to examine this figure without being impressed with the truth of the principles on which we are working, and with the further fact that these generalised results are in accord with the evidence previously set forth.

Compare, for example, the relative cerebral development of the mentally deficient, and deaf and dumb boys of the thirteenth year of life with normal boys of the same age; or the relative development of the twenty year old criminal with the University student of like age. Lastly, observe the lowly place taken by the evolutionary backward Australian Aboriginal, who is seen only to have the cerebral development of the twelve year old school boy. The whole graph conforms, in every detail, to the general principles upon which we are working and which we are seeking to establish.

Cubic Capacity of Brain in the Male During the Educational Period of Life

It has already been pointed out that, notwithstanding that there is an extensive literature on the subject of brain weights at the different periods of life, nothing whatever had hitherto been known as to the cubic capacity of brain of the living subject during the years of growth and

Figure 2



GRAPH OF THE GENERALISED RESULTS OF THE CUBIC CAPACITY OF BRAIN
OF THE NORMAL - ABNORMAL - AND ABORIGINAL GROUPS OF CASES.

Table No. 2

TABLE OF 2104 VICTORIAN PUBLIC SCHOOL BOYS AND MELBOURNE UNIVERSITY STUDENT
SHOWING THE AGES, NUMBERS, TRUE MEANS OF THE CUBIC CAPACITIES
STANDARD DEVIATIONS AND INDIVIDUAL RANGES OF VARIATION.

	Number of Cases.	Individual Minimum Cubic Capacity.	True Mean of Cubic Capacity. Probable Error True Mean.	Standard Deviation. Probable Error Standard Deviation.	Individual Maximum Cubic Capacity.	Total Individual Range
7th. 8th. & 9th. Years of Life.	63	1160	1295.32±5.92	69.71±4.19	1480	320
10th. Year of Life.	85	1124	1301.33±4.45	60.86±3.15	1504	370
11th. Year of Life.	98	1194	1317.17±4.17	61.08±2.94	1489	295
12th. Year of Life.	109	1158	1326.73±5.28	81.67±3.73	1593	435
13th. Year of Life.	153	1166	1351.89±4.03	73.94±2.85	1539	373
14th. Year of Life.	223	1162	1358.71±3.55	78.52±2.51	1690	528
15th. Year of Life.	275	1135	1378.04±3.38	83.00±2.39	1608	473
16th. Year of Life.	326	1127	1402.18±2.95	78.92±2.08	1593	466
17th. Year of Life.	312	1225	1422.06±3.01	78.75±2.13	1655	433
18th. Year of Life.	200	1145	1447.25±3.98	83.38±2.81	1653	508
19th. Year of Life.	111	1182	1463.42±4.79	74.76±3.38	1637	455
20th-30th. Years of Life.	149	1272	1483.24±4.36	78.94±3.08	1669	397

education, and that a knowledge of brain weights, as obtained after death, is of little use to those engaged in the study of the living child.

In Tables 2 and 3 there is set forth, for the first time, the mean capacity of brain of the normal healthy boy at every year of life during his educational career. As both tables deal only with one class, the Victorian Public School boy and the University student, there is presented a continuous picture of brain growth during the whole period of education, and one which is free from possible sources of error due to admixture of different social grades, from interruptions in the educational career, or from the personal errors of a number of different observers. The State School boys were included in another table, because they were found to be drawn from a different social grade of the population, to have a uniformly lower cubic capacity mean, and to cease their scholastic education at or about the age of fourteen years, making it impossible to obtain an uninterrupted picture of brain growth into the years of manhood. Even as thus restricted to one social grade the tables include numbers sufficient to make the general results free from gross mathematical error. The figures for brain capacity may, therefore, be accepted as a reasonable indication of the amount of brain which should be possessed by the average normal, well educated school boy or youth.

Table 2 sets forth, for one social grade, the numbers of cases in each year of educational life, the true means of the cubic capacity of brain, the probable errors of the means, the standard deviations from the means with their probable errors, the extreme individual cubic capacities in each year, and the total individual range of the cubic capacities.

As brain growth is generally regarded as ceasing at, or before, the twentieth year, we have grouped all individuals of more than 20 years of age, and less than 30 years of age into a single decade—the third decade of life. Concentrating attention on this group, Table 2 shows that the amount of brain which a normal healthy educated youth in the third decade of life may be reasonably expected to possess is 1483cc, and that the standard deviation therefrom is 78.94, or in round numbers, 79. This means that the majority of University students of this age will possess something between 1404cc. of brain ($1483-79$), and 1562cc. of brain ($1483 + 79$), and such individuals may be regarded, all other things being equal, as having a normal brain size. Table 2 shows that two youths departed altogether from the normal and are far outside the range of the standard deviations—the one having but 1272cc., and the other 1669cc. Expressed in terms of years, the former is, as the table shows, eleven years retarded, that is, he has but the brains of an average 9 year old boy. The table shows the same startling difference in the extremes of every year dealt with.

Extension of the Observations on the Cubic Capacity of Brain in the Male from the Educational Period of Life to Every Year of Growth

Impressed as we were with these significant facts, we realized the importance of estimating the cubic capacity of brain, not only during the educational period, but at all periods of growth from birth to the adult condition. As we had not examined the heads of infants, nor indeed have we done so even yet, we determined to estimate the cubic capacity of brain for the earlier years of life by calculation—the calculation to be checked at every stage by comparison with brain weights and other accurately known data.

From the published observations of Boyd (28), Pfister (29), Marchand (30), Vierordt (31), and others, it is known that the average weight of the brain of the newly born child is about 371 grammes, that during the first year of life the brain weight multiplies itself by 2.4, and that on the first birthday it has attained a total weight of 885 grammes. At the second birthday the brain weight averages about 984 grammes; at the third birthday, 1,097 grammes, and at the fourth birthday, 1,183 grammes. It is currently accepted, that with the attainment of the fourth birthday the brain has attained 80 per cent. of its total volume and has trebled its weight. It is also stated by Keith (17), that at birth the brain has attained to within 20 or 22 per cent. of its total volume. In our judgment and experience this last is too low and is more probably 30 per cent. We have therefore taken an intermediate reading of 25 per cent., as representing the total volume of brain at birth. As all the figures of cubic capacities of brain from the sixth year onwards were known to us from our own observations on living State School and Public School boys, and with the preceding data to guide us, it is evident that the subsequent calculations of brain capacities for the years of infancy presented no very great difficulties.

The results of these calculations are shown in Table 3, which supplements Table 2. Table 3 sets forth the recorded brain weights used as checks on the calculations, the mean of the cubic capacity of brain from birth onwards—estimated for the first six years and as observed for the remaining years, the yearly increment of the brain cubic capacity, the yearly percentage volume of brain, and as further checks on the observations there are included the medians of the brain capacities and the periodical brain increments of both means and medians in the four great periods of growth—prepubescent, resting, pubescent, and post-pubescent.

The agreement of all these observations is sufficiently close as to warrant the acceptance of the figures of brain capacity as being reasonably

Table No. 3

Year of Life.	Brain Weight, Boyd.	Brain Weight, Plister.	Brain Weight, Marchand.	Brain Weight, Vierordt.	Average Brain Weight.	Yearly Ratio of Brain Weight Increment.	True Mean of Cubic Capacity.	Yearly Increment in cc.	Percentage Volume of Brain.	Median of Cubic Capacity.	Yearly Increment in cc.	Percentage Volume of Brain.	Periodical Increment of Mean in cc.	Periodical Increment of Median in cc.
Pre-Pubertal.														
Birth.	393	340	371	381	371	—	371	—	25.0%	371	—	25.0%		
1st.	777	851	967	945	885	$\times 2.4$	945	574	63.7%	943	572	63.7%		
2nd.	941	958	1011	1025	984	$\times 2.6$	1075	130	72.5%	1074	131	72.5%		
3rd.	1097	1099	1080	1112	1097	$\times 2.9$	1151	76	77.6%	1149	75	77.6%		
4th.		1183			1183	$\times 3.1$	1186	35	80.0%	1185	36	80.0%		
5th.			1273				1206	20	81.3%	1204	19	81.3%		
6th.			1343				1225	19	82.6%	1225	21	82.7%		
7th.	1140	1219					1244	19	83.9%	1244	19	84.0%		
8th.							1264	20	85.2%	1263	19	85.3%		
9th.							1283	19	86.5%	1283	20	86.6%		
10th.							1301	18	87.7%	1304	21	88.0%		
11th.	1304	1289					1317	16	88.8%	1315	11	88.8%	946cc.	944cc.
12th.							1326	9	89.4%	1323	8	89.3%	9cc.	8cc.
13th.							1351	25	91.1%	1340	17	90.5%		
14th.		1346					1358	7	91.6%	1357	17	91.6%	32cc.	34cc.
15th.							1378	20	92.9%	1377	20	93.0%		
16th.							1402	24	94.5%	1404	27	94.8%		
17th.		1404					1422	20	95.9%	1415	11	95.5%		
18th.	1376						1447	25	97.6%	1448	33	97.8%		
19th.							1463	16	98.6%	1466	18	99.0%		
20-30.							1483	20	100 %	1481	15	100 %	125cc.	124cc.

TABLE SHOWING THE PERCENTAGE VOLUME OF BRAIN FOR ALL PERIODS OF EDUCATIONAL LIFE FROM BIRTH ONWARDS.

Mode of Calculation.—From the 6th. year of life onwards the percentage volumes of brain are calculated from the measurements taken.

From birth to the 5th. year inclusive the percentage volumes are obtained by calculation checked from recorded brain weights.

Table No. 4

TABLE OF 2717 VICTORIAN PUBLIC SCHOOL GIRLS, STATE SCHOOL GIRLS AND MELBOURNE UNIVERSITY WOMEN STUDENTS SHOWING THE AGES, NUMBERS, TRUE MEANS OF THE CUBIC CAPACITIES, STANDARD DEVIATIONS, MEDIAN OF CUBIC CAPACITIES AND INDIVIDUAL RANGES OF VARIATION.

Year of Life.	Number of Cases.	Individual Minimum Cubic Capacity.	True Mean of Cubic Capacity.	Probable Error of Mean.	Standard Deviation.	Probable Error Standard Deviation.	Median of Cubic Capacity.	Total Individual Range of Cubic Capacity.
7th.	56	976	1145.89	± 6.99	77.60	± 4.95	1140	384
8th.	81	964	1162.21	± 5.66	75.50	± 4.00	1156	383
9th.	97	995	1172.67	± 5.70	83.09	± 4.02	1184	440
10th.	142	1051	1198.88	± 4.37	77.12	± 3.09	1195	504
11th.	169	1007	1216.83	± 4.86	93.64	± 3.44	1215	501
12th.	155	1003	1226.25	± 5.12	94.44	± 3.62	1224	470
13th.	202	1031	1256.72	± 3.94	82.97	± 2.78	1256	484
14th.	255	1026	1270.79	± 3.64	86.09	± 2.57	1265	520
15th.	370	1018	1278.83	± 3.12	89.01	± 2.21	1277	517
16th.	413	1079	1303.74	± 2.98	89.71	± 2.11	1298	530
17th.	335	1061	1305.01	± 3.26	88.38	± 2.31	1301	494
18th.	184	1118	1307.31	± 4.52	90.84	± 3.19	1300	504
19th.	95	1123	1324.50	± 5.82	84.10	± 4.12	1326	471
20-30th.	163	1099	1333.07	± 4.86	91.99	± 3.44	1328	532

accurate from birth to the fifth year inclusive, and as accurate thereafter, inasmuch as they are the result of direct observation.

Cubic Capacity of Female Brain During the Educational Period of Life

In Table 4 there is set forth, for the first time, the mean capacity of brain of the normal healthy girl at every year of her educational life. It is to be specially noted that the true means of the brain capacities are calculated by Lee's female formula, which uniformly gives less results than the male formula. This being so, no direct comparison must be made between the male and the female results. In practically all other respects the Table resembles that for the males, namely Table No. 2, and again displays the enormous individual variations.

Extension of the Observations on the Cubic Capacity of Brain in the Female from the Educational Period of Life to Every Year of Growth

Table 5 sets forth for the girls what Table 3 does for the boys, and the calculations are obtained in the manner already explained. As the figures for the boys are included, the table allows of a direct comparison being established between the percentage volume of brain of boys and girls at every period of life during the growing period. The same comparison is made graphically in Figure 3. It is thus seen that the girl is more precocious in her cerebral growth than the boy, and attains her full cerebral growth, on an average, at a slightly earlier period of life.

Influence of Education on Brain Growth

From the educational standpoint Table 5 and the accompanying Figure 3 are of considerable interest. They show that in both sexes brain growth falls, during the educational period of life, quite naturally into four periods.

There is first a pre-pubescent period, which covers roughly the first ten and a half years of life, during which the brain volume attains 88.8 per cent. of its adult total in the boy, and 91.3 per cent. in the girl.

There is secondly a resting phase of one year—from the eleventh to the twelfth year—immediately preceding the onset of puberty. During this year brain growth is almost stationary in both sexes and only increases by 0.6 per cent.

There next follows a third period of two years—from the twelfth to the fourteenth years—co-incident with puberty, during which the brain increases by 2.2 per cent. in the boy and 3.4 per cent. in the girl, and attains to within 91.6 per cent. and 95.3 per cent., respectively, of the total adult volume.

Table No. 5

TABLE SHOWING THE RELATIVE PERCENTAGE VOLUME OF BRAIN IN BOYS AND GIRLS
FOR ALL PERIODS OF EDUCATIONAL LIFE FROM BIRTH ONWARDS.

Year of Life.	Numbers of Girls.	Median of Cubic Capacity—Girls.	Mean of Cubic Capacity—Girls.	Percentage Volume of Brain—Girls.	Percentage Volume of Brain—Boys.	Mean of Cubic Capacity—Boys.	Median of Cubic Capacity—Boys.	Periodical Increment of Brain Volume—Girls.	Periodical Increment of Brain Volume—Boys.	
Birth.			333	25.0	25.0	371	371			Pre-Pubesce
1st.			849	63.7	63.7	945	943			
2nd.			966	72.5	72.5	1075	1074			
3rd.			1035	77.6	77.6	1151	1149			
4th.			1066	80.0	80.0	1186	1185			
5th.			1096	82.2	81.3	1206	1204			
6th.			1121	84.1	82.6	1225	1225			
7th.	56	1140	1146	85.6	83.9	1244	1244			
8th.	81	1156	1162	87.1	85.2	1264	1263			
9th.	97	1184	1173	88.0	86.5	1283	1283			
10th.	142	1195	1199	89.9	87.7	1301	1304			
11th.	169	1215	1217	91.3	88.8	1317	1315	91.3	88.8	
12th.	155	1224	1226	91.9	89.4	1326	1323	0.6	0.6	Resting.
13th.	202	1256	1257	94.3	91.1	1351	1340			Pubescent
14th.	255	1265	1271	95.3	91.6	1358	1357	3.4	2.2	
15th.	370	1277	1279	95.9	92.9	1378	1377			Post-Pubesce
16th.	413	1298	1304	97.8	94.5	1402	1404			
17th.	335	1301	1305	97.9	95.9	1422	1415			
18th.	184	1300	1307	98.0	97.6	1447	1448			
19th.	95	1326	1324	99.3	98.6	1463	1466			
20-30.	163	1328	1333	100.0	100.0	1438	1481	4.7	8.4	

Figure 3

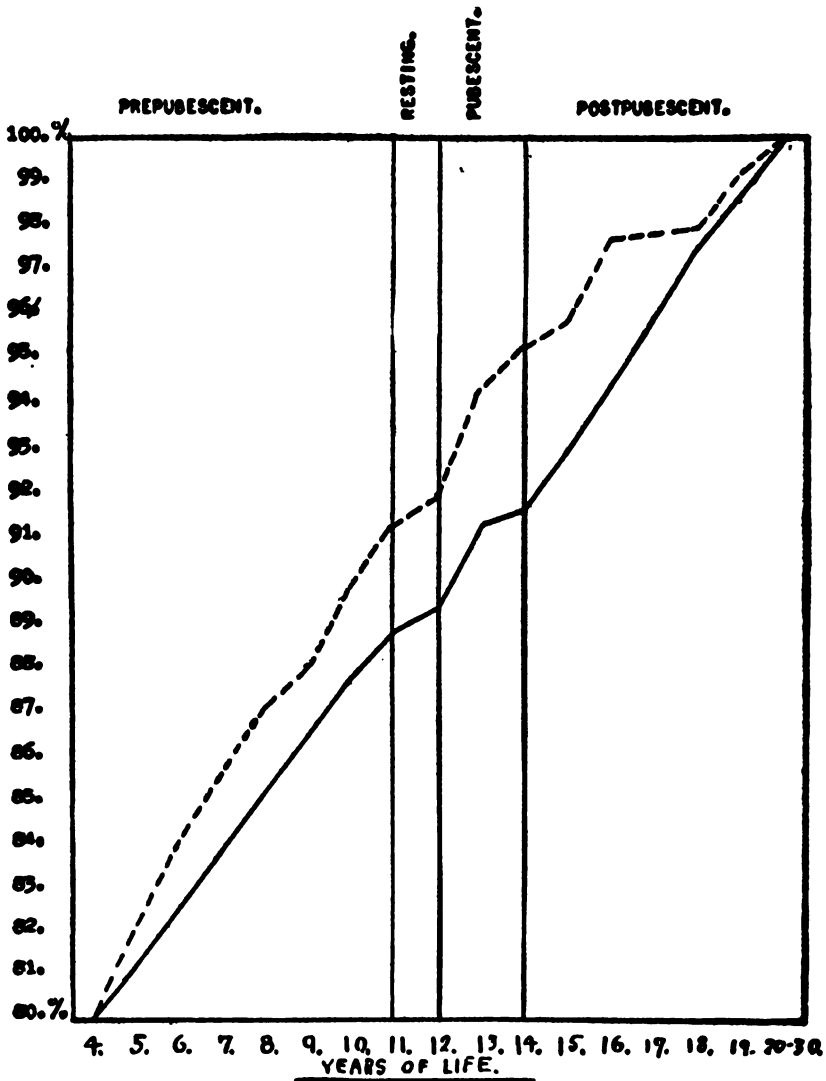


CHART ILLUSTRATING THE RELATIVE AMOUNT OF YEARLY BRAIN GROWTH IN
 MALES AND FEMALES, BASED ON THE PERCENTAGE VOLUME INCREMENTS
 OF BRAIN IN 4821 INDIVIDUALS.
 DOTTED LINE REPRESENTS 2717 GIRLS.
 CONTINUOUS LINE REPRESENTS 2104 BOYS.

Lastly comes a fourth period of six or more years, which takes the individual into adult life. This is a post-pubescent period during which the brain completes its growth and adds to its volume 8.4 per cent. in the boy, and 4.7 per cent. in the girl.

There is irrefutable evidence that in a large percentage of the population, brain growth ceases at an average level considerably below that of the normal average level at the twentieth year. In Figure I, the Benevolent Asylum inmates had an average brain capacity between the medians for sixteen and seventeen years. The Australian aborigine has an average brain capacity between the normal medians for twelve and thirteen years; and twenty year old criminals, when compared with the State School population, who are more nearly their own social grade, are at little more than a thirteen year level. Recent work has shown that development, as measured by tests, ceases in a very large proportion of the population at about the level of fourteen years. Apparently, in primitive races, in delinquent types, and in the lower social grades of the population, the post-pubescent brain development is limited in extent and duration, when compared with that of the educated or more intellectual class of the population. Doubtless, it is the supra-granular or controlling layer of the cerebral cortex that lacks full development, a deficiency which reflects itself in a generally diminished brain capacity. Here, as we previously pointed out, is the physical basis of a great percentage of pauperism, vice, and crime.

Determination of the Frontiers of Cerebral Abnormality

Having ascertained the normal capacity of brain which the normal boy or girl may reasonably be expected to possess, it now becomes necessary to determine how far deviations from the norms are to be regarded as affording a first approximation of the possible cerebral abnormality.

To take the standard deviation as a unit of measurement, and to regard cerebral abnormality as being constituted by $1\frac{1}{2}$ times the range of the deviation from the mean would be in accordance with ordinary procedure, but would allow too many cases to escape examination. In 6,281 school boys examined by us, 86.9 per cent. were found to fall, as regards their cubic capacity of brain, within a range of $1\frac{1}{2}$ times the standard deviation. 5.9 per cent. were on the minus or microcephalic side of that unit, and the remaining 7.2 per cent. were on the plus or macrocephalic side.

Accordingly, the percentile method (See Yule, 27), has been adopted by us as affording an indication of possible cerebral abnormality. Simply expressed, these percentile tables are obtained by arranging the series of observations in order from the lowest to the highest. The lowest reading

Table No. 6

TABLE OF PERCENTILES OF 4177 VICTORIAN STATE SCHOOL BOYS.

Range of Percentiles.	7th. Year of Life.	8th. Year of Life.	9th. Year of Life.	10th. Year of Life.	11th. Year of Life.	12th. Year of Life.	13th. Year of Life.	14th. Year of Life.
0.	1074	1093	1049	1092	1104	1110	1133	1081
10.	1151	1173	1183	1196	1202	1202	1214	1231
20.	1181	1196	1213	1223	1233	1233	1250	1267
30.	1196	1220	1237	1241	1251	1258	1273	1288
40.	1217	1238	1249	1259	1273	1278	1293	1308
50.	1232	1253	1265	1277	1289	1298	1310	1330
60.	1243	1269	1279	1294	1306	1315	1329	1348
70.	1265	1286	1299	1312	1331	1336	1349	1368
80.	1289	1313	1324	1349	1354	1364	1379	1397
90.	1324	1347	1354	1380	1384	1397	1413	1439
100.	1432	1497	1504	1517	1604	1587	1540	1630

The mentally abnormal types will tend to be found below the 10 percentile and above the 90 percentile.

The 50 percentile indicates the median for each year.

is the zero percentile and the highest is the 100 percentile. The remaining percentiles (properly "deciles") are the readings obtained from the division of the series into tenths. Thus, if there are 500 observations in the series, the 50th reading from the lowest will be the 10 percentile (approximately); the 100th reading the 20 percentile; the 150th reading the 30 percentile, and so on. The 50 percentile equals the "median," and in a normal distribution of cases corresponds to the average or the true mean.*

It will be observed that those cases which fall below the 10 percentile, or above the 90 percentile, depart very considerably from the type. Were it the stature of adult men with which the percentiles dealt, the dwarfs would fall below the 10 percentile, the giants above the 90 percentile, and the average around the 50 percentile or median.

We propose to regard only those brain capacities which fall outside these extreme percentiles as being potentially abnormal. In other words, measurements above the 90 percentile are regarded as macrocephalic, and those below the 10 percentile as microcephalic. Within the normal limits, then, are included 80 per cent. of the measurements as against the 66 per cent. or the 87 per cent. included when we take either the standard deviation or $1\frac{1}{2}$ S. D. as the limit of normality in brain size.

In Table 6 there is set forth, for the first time, the percentiles of cubic capacity of brain of boys of an average grade of population between the ages of 6 and 14 years. It comprises only Victorian State School boys, and as these boys unfortunately leave school in the fourteenth year, it is impossible to supply the figures for the later years. This table should be used for average grade populations.

In Table 7 is set forth the corresponding table of brain capacity percentiles for Victorian Public School boys and Melbourne University students, that is, for a higher grade type of population where the family surroundings and environment are of a more comfortable character. The table is complete from the 9th year to adolescence.

In Table 8 is set forth the percentile table for the better class type of girl and University woman student. It thus corresponds to Table 7. The figures are here calculated by means of Lee's female formula. As we are of opinion that this formula should not be used, so also we do not recommend the use of this table.

In Table 9 is set forth the percentile table for the higher social type of girl and University woman student calculated by means of the male formula. This constitutes the table which, in our opinion, should be used for the female.

In Table 10 are combined the percentiles for the three grades of

*For the exact method of calculating the deciles or percentiles see Yule's Theory of Statistics, p. 150, *et seq.*

Table No. 7

TABLE OF PERCENTILES OF 2104 VICTORIAN PUBLIC SCHOOL BOYS AND MELBOURNE UNIVERSITY STUDENTS.

Range of Percentiles.	7th. 8th. and 9th. Years of Life.	10th. Year of Life.	11th. Year of Life.	12th. Year of Life.	13th. Year of Life.	14th. Year of Life.	15th. Year of Life.	16th. Year of Life.	17th. Year of Life.	18th. Year of Life.	19th. Year of Life.	20th. to 30th. Years of Life.
0	1160	1124	1194	1158	1166	1162	1135	1127	1225	1145	1182	1272
10	1206	1222	1239	1224	1263	1255	1265	1307	1320	1350	1381	1370
20	1227	1256	1265	1255	1293	1292	1308	1336	1356	1380	1403	1411
30	1257	1269	1279	1278	1312	1318	1330	1360	1386	1403	1427	1442
40	1264	1295	1293	1295	1323	1338	1352	1382	1401	1423	1448	1463
50	1282	1304	1315	1323	1338	1357	1377	1404	1415	1448	1466	1481
60	1297	1316	1333	1349	1362	1373	1398	1425	1434	1467	1483	1509
70	1333	1326	1354	1360	1382	1391	1426	1452	1459	1486	1495	1528
80	1344	1345	1378	1387	1417	1412	1460	1477	1483	1520	1520	1553
90	1380	1372	1399	1428	1447	1455	1487	1507	1522	1551	1551	1589
100	1480	1504	1489	1593	1539	1690	1608	1593	1655	1653	1637	1669

The mentally abnormal types will tend to be found below the 10 percentile and above the 90 percentile.

The 50 percentile indicates the median for each year.

Table No. 8

**TABLE OF PERCENTILES OF 2717 VICTORIAN PUBLIC SCHOOL GIRLS, STATE SCHOOL GIRLS
AND MELBOURNE UNIVERSITY WOMEN STUDENTS AS CALCULATED FROM LEE'S
FORMULA No. 14. FEMALE FORMULA.**

Range of Percentiles.	7th Year of Life.	8th. Year of Life.	9th. Year of Life.	10th. Year of Life.	11th. Year of Life.	12th. Year of Life.	13th. Year of Life.	14th. Year of Life.	15th. Year of Life.	16th. Year of Life.	17th. Year of Life.	18th. Year of Life.	19th. Year of Life.	20-30 Years of Life.
0.	976	964	995	1051	1007	1003	1031	1026	1103	1079	1061	1126	1123	1140
10.	1052	1073	1066	1102	1106	1109	1151	1166	1192	1190	1188	1201	1225	1212
20.	1074	1099	1095	1131	1144	1141	1188	1205	1214	1231	1227	1227	1254	1255
30.	1096	1113	1126	1165	1164	1169	1211	1231	1233	1257	1260	1251	1279	1295
40.	1121	1143	1151	1178	1193	1203	1230	1247	1256	1276	1281	1271	1298	1307
50.	1140	1157	1184	1195	1215	1224	1256	1265	1277	1299	1301	1300	1326	1328
60.	1160	1174	1197	1219	1226	1242	1275	1297	1306	1321	1325	1323	1356	1349
70.	1185	1193	1218	1229	1242	1271	1299	1314	1337	1342	1343	1352	1364	1363
80.	1210	1209	1234	1252	1296	1309	1325	1333	1365	1366	1378	1394	1396	1392
90.	1249	1243	1270	1280	1348	1364	1362	1370	1420	1419	1416	1430	1418	1450
100.	1360	1347	1437	1555	1508	1473	1515	1546	1535	1609	1555	1622	1594	1631

population which we have examined, namely, (1) the State School boy, 2) the Public School boy and University student, and (3) the Public school girl and University woman student.

Cases whose brain capacity falls below the 10 percentile, or above the 90 percentile of the above tables are to be regarded as being probably, not actually, abnormal in cerebral development and should be set aside for complete and thorough examination.

Proportions of Feeble-Mindedness Amongst the Potentially Abnormal Cases

Having determined the normal levels of brain capacity in the growing boy and girl, the range of deviation from those norms, and the frontiers of potential cerebral abnormality, it next became necessary to examine those cases which fell below the 10 percentile and above the 90 percentile in order to determine what, if any, correlation existed between abnormal cerebral capacity and mental subnormality. With this object two hundred individuals (State School Boys) falling within the percentile mentioned (See Table 6) were submitted to a mental examination by the Binet-Simon and Porteus Tests with the following results:

A. Microcephalic Group (below the 10 percentile).	
At feeble-minded levels.....	18.5%
Distinctly dull.....	32.0%
	<hr/>
Total subnormal cases.....	50.5%
	<hr/>
Super-intelligent	1.25%
Distinctly above average	2.75%
Total above average intelligence	5.0%
B. Macrocephalic Group (above the 90 percentile).	
At feeble-minded levels.....	5.0%
Distinctly dull	9.0%
	<hr/>
Total subnormal	14.0%
	<hr/>
Super-intelligent	9.0%
Distinctly above average.....	16.0%
	<hr/>
Total above average intelligence.....	25.0%
	<hr/>

Of the microcephalic or 10 percentile group 50.0% are subnormal, but the macrocephalic or 90 percentile group only 14.0% are so.

Of the macrocephalic or 90 percentile group 25.0% are above average

Table No. 9

**TABLE OF PERCENTILES OF BRAIN CAPACITY OF 2717 VICTORIAN PUBLIC SCHOOL AND
STATE SCHOOL GIRLS AND MELBOURNE UNIVERSITY WOMEN STUDENTS.**

CALCULATED FROM LEE'S MALE FORMULA No. 14.

$11 \times .000337$ PLUS 406.01.

	7th.	8th.	9th.	10th.	11th.	12th.	13th.	14th.	15th.	16th.	17th.	18th.	19th.	20-30 Year.
0	1054	1044	1070	1118	1080	1077	1100	1097	1161	1141	1126	1151	1178	1192
10	1118	1136	1130	1160	1165	1167	1202	1214	1236	1235	1233	1244	1264	1253
20	1137	1158	1155	1185	1195	1193	1233	1247	1254	1269	1266	1265	1289	1289
30	1155	1169	1182	1213	1213	1218	1242	1269	1270	1291	1294	1286	1310	1322
40	1177	1195	1201	1225	1237	1246	1268	1283	1290	1307	1311	1303	1326	1333
50	1193	1207	1230	1239	1255	1263	1290	1298	1308	1326	1328	1328	1349	1351
60	1209	1221	1240	1259	1266	1278	1306	1324	1332	1345	1348	1347	1374	1368
70	1230	1237	1258	1267	1281	1303	1326	1339	1358	1362	1363	1371	1381	1389
80	1251	1251	1271	1287	1324	1335	1348	1355	1382	1383	1393	1406	1408	1401
90	1284	1279	1302	1309	1368	1381	1384	1387	1428	1427	1425	1436	1427	1455
100	1378	1367	1442	1542	1502	1473	1508	1534	1526	1588	1542	1598	1575	1601

The mentally abnormal types will tend to be found below the 10 percentile and above the 90 percentile. The 50 percentile indicates the median for each year.

TABLE OF PERCENTILES OF BRAIN CAPACITY VS. AGE
SCHOOL GIRLS AND MELBOURNE UNIVERSITY WOMEN STUDENTS AND 2104 VICTORIAN PUBLIC SCHOOL BOYS AND
MELBOURNE UNIVERSITY STUDENTS. NUMBER OF CASES 8998. CALCULATED FROM LEE'S MALE FORMULA NO. 14.

	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20-30	Year of Life.
0	1074 1054	1093 1044	1049 1160	1092 1124	1104 1194	1110 1158	1133 1166	1081 1162	1161 1135	1141 1127	1126 1225	1151 1145	1178 1182	1192 1272	State Sc. Boys. Girls. Public Sc. Boys.
10	1151 1118	1173 1136	1183 1206	1196 1222	1202 1239	1202 1224	1214 1263	1214 1255	1236 1265	1235 1307	1233 1320	1244 1350	1264 1381	1253 1370	State Sc. Boys. Girls. Public Sc. Boys.
20	1181 1137	1196 1158	1213 1227	1223 1256	1233 1265	1233 1255	1250 1293	1267 1292	1254 1308	1269 1336	1266 1356	1265 1380	1289 1411	1289 1411	State Sc. Boys. Girls. Public Sc. Boys.
30	1196 1155	1220 1169	1237 1257	1241 1269	1251 1279	1258 1278	1273 1312	1288 1318	1270 1330	1291 1360	1294 1386	1286 1403	1310 1427	1322 1442	State Sc. Boys. Girls. Public Sc. Boys.
40	1217 1177	1238 1195	1249 1201	1259 1225	1273 1237	1278 1246	1293 1323	1308 1338	1290 1352	1307 1382	1311 1401	1303 1423	1326 1448	1333 1463	State Sc. Boys. Girls. Public Sc. Boys.
50	1232 1193	1253 1207	1265 1230	1277 1239	1289 1255	1298 1263	1310 1340	1330 1357	1308 1377	1326 1404	1328 1415	1328 1448	1349 1466	1351 1481	State Sc. Boys. Girls. Public Sc. Boys.
60	1243 1209	1269 1221	1279 1297	1294 1316	1306 1333	1315 1349	1329 1362	1348 1373	1332 1398	1345 1425	1348 1434	1347 1467	1374 1483	1368 1509	State Sc. Boys. Girls. Public Sc. Boys.
70	1265 1230	1286 1237	1299 1333	1312 1326	1331 1354	1336 1360	1349 1382	1368 1391	1358 1426	1362 1452	1363 1459	1371 1486	1381 1495	1380 1528	State Sc. Boys. Girls. Public Sc. Boys.
80	1289 1251	1313 1251	1324 1344	1349 1345	1354 1378	1364 1387	1379 1417	1397 1412	1382 1460	1383 1477	1393 1483	1406 1520	1408 1520	1405 1553	State Sc. Boys. Girls. Public Sc. Boys.
90	1324 1284	1347 1279	1354 1380	1380 1372	1384 1399	1397 1428	1413 1447	1439 1455	1428 1487	1427 1507	1425 1522	1436 1551	1427 1551	1453 1589	State Sc. Boys. Girls. Public Sc. Boys.
100	1432 1378	1497 1367	1504 1442	1517 1542	1604 1502	1587 1473	1540 1508	1630 1534	1526 1608	1588 1593	1542 1655	1598 1653	1575 1637	1606 1669	State Sc. Boys. Girls. Public Sc. Boys.

The mentally abnormal types will tend to be found below the 10 percentile and above the 90 percentile. The 50 percentile indicates the median or average for each year.

intelligence, whilst only 5.0% of the microcephalic or 10 percentile group are so.

That one-half of the 10 percentile group is of subnormal mentality is in accordance with the principles on which we are working. That *all* are not so is simply due to the fact that head measurements cannot differentiate between the varying contents of the skull. That a small percentage of this group are distinctly above average intelligence, even to the possession of super-intelligence, is also in accordance with the known facts, since it is certain that the amount of grey cortical matter, especially of certain regions concerned in some particular phase of mental activity may exist in unusual abundance—hence the occurrence of genius of the small-headed type.

That a large percentage of the macrocephalic or 90 percentile group is above average intelligence is strictly in accordance with known neurological facts. That all are not so is due to the disturbing influences of excess of cerebro-spinal fluid, or varying ratios of neurone or neuroglia, which head measurements cannot discover. For these reasons it is, therefore, only to be expected that a percentage of the macrocephalic group would be of subnormal intelligence.

It has not been possible for us to examine the remaining percentiles in the same way, as we have had neither the staff nor the time. We fully recognize that such an examination of all the percentiles is required. We are not, therefore, in a position to state what percentage of mental subnormality occurs in the intermediate groups of percentiles. On general grounds we should expect the percentage of mental subnormality to fall from the 10 percentile to the 50 percentile or median fairly steeply, and then to rise similarly to the 90 percentile.

It consequently follows that the use of brain capacity estimation and the resulting percentile tables will not detect all cases of even possible mental subnormality. It does, however, form a rapid method of obtaining a first approximation of possible cerebral abnormality, which, by its very simplicity, is readily available to all engaged in mental diagnosis. Many a case of otherwise unsuspected mental abnormality will thus be brought to light.

Length, Breadth, and Height of the Head in the Male During the Educational Period of Life

In Table 11 are set forth the results of our investigations of the means of head lengths, head breadths, and head heights of the normal male during the educational years of life. There are included in this table Public School boys and University students only. The large numbers of State School boys available have been excluded because they were not

Table No. 11'

TABLE OF THE HEAD FORM OF 2097 VICTORIAN PUBLIC SCHOOL BOYS AND
MELBOURNE UNIVERSITY STUDENTS.

Year of Life.	True Mean of Length.	Probable Error.	Standard Deviation of Length.	Probable Error.	True Mean of Breadth.	Probable Error.	Standard Deviation of Breadth.	Probable Error.	True Mean of Height.	Probable Error.	Standard Deviation of Height.	Probable Error.	Cubic Capacity of Brain as Calculated from Head Measurements.	Number of Cases.
7th 8th 9th	182.66	.43	5.16	.31	145.20	.35	4.19	.25	125.68	.35	4.14	.22	1296	63
10th	183.81	.32	4.45	.23	144.71	.34	4.74	.24	126.11	.29	3.97	.20	1302	85
11th	184.03	.31	4.63	.22	145.62	.26	3.95	.19	126.85	.27	4.09	.19	1315	98
12th	184.44	.37	5.76	.26	146.69	.29	4.63	.21	127.11	.31	4.83	.22	1326	109
13th	186.59	.33	6.09	.23	147.14	.26	4.81	.18	128.13	.25	4.69	.18	1350	153
14th	186.48	.25	5.68	.18	147.77	.25	5.62	.18	128.71	.22	4.97	.15	1358	223
15th	187.57	.25	6.32	.18	148.87	.20	5.13	.14	129.35	.20	4.97	.14	1377	275
16th	188.76	.21	5.80	.15	149.86	.17	4.56	.12	130.58	.17	4.73	.12	1401	326
17th	190.02	.23	6.15	.16	150.66	.17	4.44	.12	131.44	.18	4.92	.13	1421	312
18th	191.50	.30	6.47	.21	151.71	.22	4.71	.15	132.38	.23	4.82	.16	1445	200
19th	192.44	.39	6.14	.27	152.09	.30	4.81	.21	133.37	.23	3.63	.16	1462	111
20th-30th	193.73	.33	5.84	.23	152.49	.26	4.69	.18	134.55	.29	5.22	.20	1482	142
Total													2097	

obtainable after the fourteenth year. Boys in the seventh, eighth and ninth years have had to be grouped together on account of a mathematical insufficiency of numbers. The figures, therefore, probably represent the 8-year average.

From our observations the increments of head growth during the educational period of life would appear to be as follows:—

Increment of head breadth growth.....	5.0%
Increment of head length growth.....	6.1%
Increment of head height growth.....	7.1%

These observations confirm those previously mentioned, and support the idea that, as regards brain growth, head height is the most important factor, which is in accordance with the anatomical construction of the skull which has a cartilaginous base and a membranous roof. Our studies also suggest that in the more highly educated classes, the increase in size of brain is accommodated rather by additions to the height of the skull than to the breadth, though it must be distinctly understood that deficiency in the one measurement may be, and frequently is, compensated for by an increment in another.

As the normal dimensions of the three chief diameters of the head are obviously of importance to those who are concerned with the care of the child, and as our own observations have not dealt with the earlier years of life and of infancy, we have endeavoured to supply the missing data by calculation, and so complete the picture of head growth from birth onwards.

The dimensions of the human skull at birth are very accurately known and may be given as follows:—

Maximum length	117.5mm.
Maximum breadth	92.5mm.
Maximum height	95.0mm.

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By adding approximately 3mm. to each of the foregoing as an allowance for the thickness of the soft parts of the scalp in the head of the human infant there are obtained the figures at birth as given in Table 12.

As bodily growth proceeds rapidly during the first year of life, and somewhat less so during the next three years, there are obtained by calculation the lengths, breadths and heights of the head during those years.

From the 5th to the 9th years the calculations are made on the assumption which Pearson (5) has shown to be certainly the case for breadth, that head growth, as regards single measurements, is uniform.

From the 10th year onwards the head dimensions are those actually observed by us on the living Victorian Public School boy and University student, whilst the head measurements are also known of the Victorian State School boy from the 6th to the 14th years.

Table No. 12

TABLE OF AVERAGE LENGTHS, BREADTHS AND HEIGHTS OF THE HEAD IN MALES OF
ALL AGES FROM BIRTH UP TO ADOLESCENCE.

Year of Life.	Length of Head in mm.	Percentage of Head Length.	Breadth of Head in mm.	Percentage of Head Breadth.	Height of Head in mm.	Percentage of Head Height.	Cub. Capac. of Brain as Calculated from L. B. H.	Cub. Capac. of Brain as Calculated or Observed.
Birth.	120.00	61.93	96.00	62.90	98.00	72.84	678	371
1st.	150.70	82.01	125.70	82.01	112.00	83.24	951	945
2nd.	165.62	85.50	130.24	85.40	116.22	86.40	1060	1075
3rd.	172.43	89.00	135.72	89.00	119.82	89.06	1144	1151
4th.	174.36	90.00	137.22	90.00	122.44	91.00	1180	1186
5th.	176.10	90.90	138.62	90.90	123.27	91.60	1203	1206
6th.	177.65	91.70	139.83	91.70	123.92	92.10	1223	1225
7th.	179.20	92.50	141.06	92.50	124.47	92.50	1243	1244
8th.	180.75	93.30	142.28	93.30	125.00	92.90	1262	1264
9th.	182.31	94.10	143.50	94.10	125.54	93.30	1282	1283
10th.	183.81	94.90	144.71	94.90	126.11	93.70	1302	1301
11th.	184.03	94.98	145.62	95.50	126.85	94.30	1315	1317
12th.	184.44	95.20	146.69	96.20	127.11	94.50	1326	1326
13th.	186.46	96.20	147.14	96.50	128.13	95.20	1350	1351
14th.	186.48	96.20	147.77	96.90	128.71	95.60	1358	1358
15th.	187.57	96.80	148.87	97.60	129.35	96.10	1377	1378
16th.	188.76	97.40	149.86	98.30	130.58	97.00	1401	1402
17th.	190.02	98.08	150.66	98.80	131.44	97.70	1421	1422
18th.	191.50	98.80	151.71	99.50	132.38	98.40	1445	1447
19th.	192.44	99.30	152.09	99.70	133.37	99.10	1462	1463
20-30	193.73	100.00	152.49	100.00	134.55	100.00	1482	1483

From birth to the 9th year inclusive the measurements are obtained by calculation and are, therefore, only to be regarded as an approximation. From the 10th year onwards the figures are as actually observed on the living subject.

Before these figures, as calculated for the dimensions of the head during the years of infancy, can be accepted as even reasonably accurate, they must comply with two conditions. First, the annual rate of increment must be in accord with the known facts as to the rapidity of growth. Secondly, the cubic capacities of brain as calculated from the estimated measurements must be in accord with those obtained from other sources and with the known brain weights. As the figures of the table would appear to comply with these conditions, they may be accepted as being reasonably accurate, and hence if a head departs very much from the dimensions set forth in Table 12 it may be regarded as being most probably abnormal.

Length, Breadth, and Height of the Head in the Female During the Educational Period of Life

In Table 13 are set forth the results of our investigations of the means of head lengths, head breadths, and head heights of the normal female during the educational years of life.

In Table 14 are set forth the dimensions of the female head at all periods of life from birth onwards. For the years of infancy the figures are calculated in the same way as were those for the boys.

Sexual Differences in the Size of the Head

A comparison of the head measurements of the two sexes, as set forth in Tables 11 and 13, will show that the female has at all periods of life a slightly smaller average head than has the male. This is in strict accordance with the other known phenomena of ratios of bodily size of the two sexes. It affords the proof of our previous observation that it is unnecessary to use a different formula for the calculation of the brain capacity in the two sexes. The slightly smaller head makes the necessary correction for "the ratio of male to female skull capacity" allowed for by Miss Lee. (See page 24.) To employ a formula which uniformly gives a smaller brain capacity on what is now known to be a uniformly smaller head is to double the male advantage. Hence our recommendation that in future the cubic capacity of brain should be estimated in both sexes by the one formula—Lee's Male Formula No. 14— and that the results should be compared with our female brain percentiles calculated from the male formula.

Conclusions as to the Value of Head Measurement in the Diagnosis of Mental Subnormality

Head measurement, and the calculation therefrom of the cubic capacity of brain, is not in itself a measure of intelligence.

Table No. 13

TABLE OF THE HEAD FORM OF 2717 VICTORIAN PUBLIC SCHOOL GIRLS, STATE SCHOOL GIRLS AND MELBOURNE UNIVERSITY STUDENTS.

Year of Life.	Number of Cases.	True Mean of Length.	Probable Error.	Standard Deviation of Length.	Probable Error.	True Mean of Breadth.	Probable Error.	Standard Deviation of Breadth.	Probable Error.	True Mean of Height.	Probable Error.	Standard Deviation of Height.	Probable Error.
7th.	56	173.91	.47	5.29	.33	137.66	.34	3.87	.24	124.47	.38	4.24	.27
8th.	81	175.49	.40	5.38	.28	139.11	.28	3.74	.19	124.10	.35	4.69	.24
9th.	97	175.48	.38	5.56	.26	139.91	.30	4.47	.21	124.90	.35	5.19	.25
10th.	142	177.58	.30	5.38	.21	140.39	.24	4.24	.17	125.94	.24	4.24	.17
11th.	169	178.48	.29	5.74	.21	141.22	.22	4.35	.16	126.50	.29	5.74	.21
12th.	155	179.55	.32	6.00	.23	141.66	.26	4.79	.18	126.48	.26	4.79	.18
13th.	202	180.14	.27	5.74	.19	142.68	.24	5.19	.17	127.98	.20	4.35	.14
14th.	255	182.40	.24	5.74	.17	142.57	.18	4.35	.13	128.77	.19	4.58	.13
15th.	370	182.95	.19	5.66	.14	143.78	.15	4.41	.10	129.57	.17	4.87	.12
16th.	413	183.62	.17	5.88	.13	144.41	.14	4.24	.09	129.99	.13	4.58	.10
17th.	335	183.88	.21	5.74	.15	144.53	.16	4.35	.11	129.80	.17	4.79	.12
18th.	184	184.33	.29	5.83	.20	144.72	.24	5.00	.17	129.72	.22	4.58	.16
19th.	95	184.14	.37	5.37	.26	145.86	.28	4.12	.20	130.33	.31	4.47	.21
20-30.	163	185.01	.27	5.29	.19	145.70	.25	4.89	.18	131.23	.26	5.00	.18

Table No. 14

TABLE OF THE AVERAGE LENGTHS, BREADTHS AND HEIGHTS OF THE HEAD IN FEMALES
OF ALL AGES FROM BIRTH UP TO ADOLESCENCE.

Year of Life.	Length of Head in mm.	Percentage of Head Length.	Breadth of Head in mm.	Percentage of Head Breadth.	Height of Head in mm.	Percentage of Head Height.	Cub. Capac. of Brain as Calculated from L. B. H.	Cub. Capac. of Brain as Calculated or Observed.	
Birth.	120.00	64.86	96.00	65.89	98.00	74.65			Calculated.
1st.	155.08	84.20	122.58	84.12	111.24	84.77	851	849	
2nd.	163.70	88.47	128.75	88.35	115.40	87.93	957	966	
3rd.	167.20	90.37	131.52	90.26	119.89	91.35	1027	1035	
4th.	168.82	91.50	133.55	91.65	121.58	92.64	1062	1066	
5th.	169.50	91.60	135.31	92.87	123.12	93.81	1090	1096	
6th.	171.46	92.67	136.94	93.99	124.03	94.51	1120	1121	Observed.
7th.	173.91	93.98	137.66	94.47	124.47	94.84	1143	1146	
8th.	175.49	94.83	139.11	95.47	124.10	94.57	1160	1162	
9th.	175.48	94.83	139.91	96.02	124.90	95.18	1173	1173	
10th.	177.58	95.97	140.39	96.34	125.96	95.96	1198	1199	
11th.	178.48	96.46	141.22	96.92	126.50	96.40	1214	1217	
12th.	179.55	97.04	141.66	97.22	126.48	96.40	1224	1226	
13th.	180.14	97.38	142.68	97.91	127.98	97.52	1249	1257	
14th.	182.40	98.57	142.57	97.85	128.77	98.11	1269	1271	
15th.	182.95	98.87	143.78	98.67	129.57	98.72	1289	1279	
16th.	182.62	99.24	144.41	99.11	129.99	99.04	1303	1304	
17th.	183.88	99.37	144.53	99.19	129.80	98.90	1304	1305	
18th.	184.33	99.63	144.72	99.32	129.72	98.85	1307	1307	
19th.	184.14	99.53	145.86		130.33	99.30	1321	1324	
20-30.	185.01	100.00	145.70	100.00	131.23	100.00	1334	1333	

From birth to the 6th year inclusive the measurements are obtained by calculation and are, therefore, only to be regarded as an approximation. From the 7th year onwards the figures are as actually observed on the living subject.

As mental development is dependent on brain development, striking deviation from the normal in brain size will tend to be associated with mental abnormality. When this deviation attains a certain sufficiently high degree, it must be revealed by head measurement and the calculation therefrom of brain size.

As such cases of striking deviation from the normal are due, in many instances, to developmental failure of the supra-granular layer, or layer of educability, of the cerebral cortex, and as this means a greatly diminished number of myelinated neurones, there will be a smaller sized brain, which head measurement, even in its present imperfect stage, is capable of detecting.

Small headedness is, as a general rule, of more diagnostic significance than large headedness.

The authors' percentile tables of brain capacity are distinct aids in the diagnosis of mental subnormality, and afford a more certain basis for the psychologist to work upon than has hitherto been the case, because, as stated, they afford some clue to the relative degree of development of the all-important supra-granular layer of the cerebral cortex. It is this last fact which has given this work its value, and which entitles it to the careful consideration of educationalists and psychologists.

PART II—SECTION I

PSYCHOPHYSICAL TESTS

Relation of Tests to Intelligence

The subject of the relation of physical and psychophysical tests to intelligence is of great interest. Whipple (32) summarizes the work of a number of investigators on this problem, and shows that the consensus of opinion is in favor of the view that there is a positive relation between mental and physical abilities during childhood. He attributes these correlations to relative maturity, mental and physical precocity tending to go hand in hand.

Doll (33) has carried out an investigation with regard to tests of this nature and their correlation with the mental abilities of defectives. He took the normal percentile tables of height, weight, grip, and vital capacity published by Smedley (34) and then compared the feeble-minded with these normal standards. Doll sums up the general results of this comparison as follows:—

“Compared with the Smedley percentile tables the feeble-minded of all ages and grades were clearly subnormal in physical measurements, and even more subnormal in psychophysical measurements; the amount of subnormality increased with the degree of defect.”

For correlation purposes Doll used the Binet age as an estimate of intelligence, and he reports the following results. The figures are taken from his Table 13, and are corrected for irrelevancy of chronological age.

Table No. 15

CORRELATIONS BETWEEN PERCENTILES OF PHYSICAL AND PSYCHOPHYSICAL MEASUREMENTS AND INTELLIGENCE. (Doll, Table 13.)

Sex	Standing Height	Sitting Height	Weight	Right Grip	Left Grip	Vital Capacity
Girls .....	.39	.47	.34	.69	.67	.63
Boys .....	.31	.41	.23	.62	.81	.64

It is evident that, in the case of defectives, psychophysical measurements correlate highly with intelligence. Doll notes the defective's inability to accommodate himself properly to the conditions of the test. He fails to register his full height because of the way in which he stands up to the stadiometer: similarly, in measurements of grip, he lacks the ordinary child's competitive spirit, and stops gripping the dynamometer at the point of physical discomfort. For similar reasons his spirometer records are low. Hence, these are tests not only of psychophysical capacity, but of will power, interest, ability to follow instructions, and other mental characteristics as well.

Relying on these findings, Doll proposed that the subnormality of defectives in these measurements should justify the use of anthropometry as an aid to mental diagnosis. By taking the average of the three physical measurements—standing and sitting height, weight—and comparing this with the average of the three psychophysical measurements of right and left grip and vital capacity, we arrive at the physical excess, which Doll thinks is characteristic of mental defect. Certain cases, however, show both averages much below normal.

Diagnosis of High Grade Defectives

The degree of correlation might, however, be affected by the number of low-grade cases included, and as our concern was mainly with the differentiation of the high-grade cases, it was necessary to know how these measurements correlated with mental ability in normal children. It was expected that the nearer the measurements approached normal levels the less would they partake of the nature of mental tests, and the correlations would be correspondingly reduced.

Other investigators had worked out this problem by taking the teachers' estimates as a measure of intelligence—in our opinion an unreliable method. We decided to work out the correlations, using the average of Binet and Porteus test ages as our estimates of intelligence.

This investigation was carried out by one of us (Porteus) with one group of children in 1916, and with another group in 1918. It was felt that to treat all the data together in one group, even after correction

for irrelevancy of sex and chronological age, might obscure many interesting points. Hence, in this and the following investigations, age and sex groups have been kept separate.

In several other respects our figures are not strictly comparable with Doll's. His correlations are with percentiles, ours with original measurements. Further, we adopted the plan of adding together the right and left grips so that our correlations are really with total strength of grip. In this way we thought it probable that we might avoid disturbance of correlations due to inclusion of left-handed persons.

Table No. 16

CORRELATIONS BETWEEN GRIP AND BINET AGE. 894 CASES. (Porteus, 1916.)

Age	Boys, 432 Cases				G RLS, 462 Cases			
	No. of Cases	R Values	r value	p.e. r	No. of Cases	R	r	p.e. r
6 yrs.	54	.25	.38	.08	Insufficient cases			
7 "	74	.07	.11	.08	64	Negative		
8 "	48	.16	.25	.09	62	.04	.06	.08
9 "	66	.3	.44	.07	64	.39	.57	.06
10 "	42	.18	.28	.09	70	.19	.29	.07
11 "	32	.09	.14	.11	70	.35	.52	.06
12 "	62	.1	.16	.08	80	.21	.32	.07
13 "	54	.22	.34	.08	52	.22	.34	.08

In the above table, Spearman *R* values have been converted into Pearson *r* values by means of Whipple's Table 6 (Manual of Mental and Physical Tests, p. 44).

An important factor, influencing the size of the correlations obtained in this and the following tables, is due to the treatment of cases in separate age groups. Naturally the range of ability will be restricted by this plan, so that a normal distribution is hard to obtain and the correlations may be sensibly reduced. For instance, six-year school children will probably have a comparatively smaller variation in mental age than in grip or vital capacity. In the calculation of the correlations very small differences in mental ratings will thus have undue weight. A few months' difference in mental age may mean a widely separated rank order; consequently, a positive coefficient of correlation of the order of .2 or .3 must be considered significant, whilst one of .4 or .5 must be considered high. The reasons for treating the age groups separately, rather than massing the data and then correcting the correlations for irrelevancy of chronological age, have been previously dealt with.

The foregoing table shows that in the case of boys there is, at each age, a positive correlation between the psychophysical measurements and Binet ages, but that the coefficients vary considerably, the highest being apparent at 9 years of age in both sexes. Low correlations were observed at 7 years and 11 years in the case of boys. With girls, the highest correlations were obtained at 9 and 11 years.

Table No. 17

CORRELATIONS BETWEEN GRIP AND PORTEUS TEST AGE. 894 Cases. (Porteus, 1916.)

Age	Boys (432)				Girls (462)			
	No. of Cases	R.	r.	P.E. r.	No. of Cases	R.	r.	P.E. r.
6	54	.36	.54	.06				
7	74	.23	.35	.07	64	.1	.15	.08
8	48	Negative			62	.18	.28	.08
9	66	.23	.35	.07	64	.23	.35	.07
10	42	.23	.35	.09	70	.07	.11	.08
11	32	Negative			70	.34	.51	.06
12	62	.39	.57	.06	80	.11	.17	.07
13	54	.41	.6	.06	52	.17	.26	.09

Table 17 shows that in the case of boys there are relatively higher correlations between grip and the Porteus test age, than between grip and the Binet age at every age level except two, viz, eight and eleven. The relation between grip and Porteus test age is, however, not as marked in the case of girls.

The above correlations were obtained mainly from children of the one social grade. Up to age eleven, they may be considered as a socially homogeneous group. At that age there was some admixture of children of better social standing. This may partially account for the low correlations at that age.

To explain these variations in the coefficients—assuming that they are not wholly due to errors in sampling—we would need to consider two questions:—

(1) Are there spurts and resting phases in development, and (2) what relation exists between mental precocity and the degree of physical maturity?

Some studies lend color to the belief that resting and accelerated phases in development do occur. Some as yet unpublished data in our possession point to the probability that in different social grades this periodicity has a somewhat different age incidence—more particularly in the case of boys. The trend of the evidence is toward the view that children in the lower social grades tend to reach the various developmental stages in advance of children of higher social grade. In other words, the former are physically more precocious, but have a shorter developing period. (See also P. 59.)

As regards brain capacity, a consideration of the medians given in

Table 6 will show that with boys of the lower social grade the period from the 13th to the 14th year of life is one of comparatively rapid growth. At this age there is less average difference in the brain capacity of these boys as compared with those of better social grade (see Table 7) than at any other age at which our figures permit a comparison. That is to say, the boys of lower social grade appear to reach the period of pubertal acceleration slightly in advance of the boys of better class. If the two social grades are mixed the correlations at such a period would tend to be disturbed. There is strong evidence from various sources in support of the view that there is, in physical development, a resting period at 10 years. If this is reached by children at slightly different ages, according to social grade—provided of course that the better grade children are the more intelligent—we should have, as a result, a disturbance of our correlation values from 10 years onwards, an expectation which is verified by our experience.

Table No. 18

CORRELATIONS BETWEEN GRIP AND PORTEUS TEST AGES. 1248 Cases. (Porteus, 1918.)

Age	Boys (617)				Girls (631)			
	No. of Cases	R value	r value	P.E. r	No. of Cases	R.	r.	P.E. r.
6	63	.16	.25	.08	64	.17	.26	.08
7	75	.07	.11	.07	74	.16	.25	.07
8	78	.18	.28	.07	67	.14	.22	.08
9	84	.25	.38	.06	79	.09	.14	.07
10	74	.21	.32	.07	91	.08	.13	.07
11	93	Neg.			84	.06	.09	.07
12	94	.13	.20	.07	96	.15	.23	.06
13	56	.07	.11	.09	76	Neg.		

Table 18 shows the results of examining a group of mixed social grade, by the Porteus tests. As with the Binet, the low correlations were at 7 years and 11 years, whilst generally lower coefficients were demonstrated.

The question of the influence of mental precocity still further complicates the matter. Some investigators, on the basis of Binet examinations, have stated that there is no evidence of accelerated periods. If this opinion is founded on the consideration of tables of average development it may be incorrect because the fact of periodicity may easily be concealed. If the periods do not synchronize with the dull and bright groups it may

be easily possible that at a given age, say 10 years, half of the children may be a stage ahead of the other half in physical or mental development, so that while one-half is in the accelerated period, the other half may be in the resting phase; hence the two tendencies balance each other so that for the whole group apparently the rate of development appears to be equal to that in other years. The only solution of the question will be by repeated annual measurements of the same individuals. Unfortunately, our data do not give any more than a suggestion as to the answer to these questions, and the importance of the subject is our apology for mentioning the question here.

It will easily be seen that variations in the age incidence of these presumptive periods would decidedly affect our correlations. Though comparatively large groups of children were included in our examinations, the necessity of dividing them by age and sex seriously increased the size of the probable errors.

It is noteworthy that the highest correlations were found at 9 years between Binet test age and grip for girls and boys, between grip and Porteus test age (1918 examination group of boys) and between vital capacity and Binet age (boys and girls) and between vital capacity and Porteus test age (boys). The low correlations occurring at 7 years and 11 years have already been remarked upon.

Despite the variations in the correlation coefficient the fact that we found at 12 and 13 years comparatively high correlation of the psycho-physical measurements with both Porteus and Binet test ages justified us in the inclusion of these anthropometric tests in our scheme of diagnosis.

Table No. 19

CORRELATIONS OF VITAL CAPACITY WITH BINET TEST AGE. 894 Cases. (Porteus, 1916.)

Age	Boys, 432 Cases				No. of Cases	Girls, 462 Cases		
	No. of Cases	R.	r.	P.E. r.		R.	r.	P.E. r.
6	54	.25	.38	.08				
7	74	.2	.31	.07	64	.1	.16	.08
8	48	.27	.41	.08	62	.23	.35	.07
9	66	.31	.47	.06	64	.33	.5	.06
10	42	.15	.23	.09	70	.27	.41	.07
11	32	.26	.4	.1	70	.13	.2	.08
12	62	.24	.37	.07	80	.24	.37	.06
13	54	.25	.38	.08	52	Negative		

Table No. 20

CORRELATIONS OF VITAL CAPACITY WITH PORTEUS TEST AGE. 894 Cases. (Porteus, 1916.)

Age	Boys, 432 Cases				Girls, 462 Cases			
	No. of Cases	R.	r.	P.E. r.	No. of Cases	R.	r.	P.E. r.
6	54	.13	.2	.09				
7	74	.19	.29	.07	64	.22	.34	.07
8	48	.08	.13	.09	62	.05	.07	.08
9	66	.37	.55	.06	64	.21	.32	.07
10	42	.19	.29	.09	70	.22	.33	.07
11	32	.09	.13	.11	70	.43	.62	.05
12	62	.35	.52	.06	80	.25	.38	.06
13	54	.25	.38	.08				

Summary of Conclusions

A general review of the foregoing tables shows that, on the whole, there is a positive relation between psychophysical measurements and results of mental tests. Vital capacity appears to correlate more highly with test ages than does grip. The coefficients are more uniformly high at 9 years than at any other age. At 11 years in the case of boys the correlation with grip almost disappears, but tends to rise again at 13 years. On the other hand, girls at 11 years in two investigations displayed a high correlation. As regards vital capacity, the girls again show a high correlation at 11 years with the Porteus test age, whilst this is true of the boys at 9 and 12 years. Generally speaking, the correlations at 12 years tend to be high enough to justify the use of the anthropometric method in diagnosis at this critical age. At the same time, it must be recognized that, in the case of children about the border line of normality, the value of the method may be very seriously affected by the factor of chronological age in its relation to physiological development.

Social Grade and Psychophysical Development

The results of a comparison of the average performances in psychophysical tests of children of different social grades may be summarized as follows:—

Boys of both social grades (lower and middle) have an advantage over the girls at all ages from 6 to 13 years. The lower class boys have their greatest advantage over the girls at 11 years of age; the middle class

boys have their greatest advantage a year later. The girls of both classes show their greatest annual increment of strength at 12 years, at this age the lower class girl being very little below the boy.

Comparing the sexes separately, we find that the better class boys showed superiority in every year, being most marked at 12 years. The middle class girls showed the greatest superiority at 11 years. Apparently the better class girls began their prepubertal increase slightly before the lower class. With boys the reverse appeared to be the case. Our numbers, however, are rather too small to generalize upon with safety. In all probability, the disturbances in the correlations after 9 years are due to the occurrence of resting and accelerated phases in development. The unfavorable periods appear to be in the case of boys from 9 to 10, and from 10 to 11. In girls the unfavorable period appears to be from 10 to 11 years.

Diagnostic Value of Measurements

The term "physical excess," as used by Doll, has already been explained as the difference between the physical and psychophysical averages, and his results demonstrate that this physical excess occurs in a very large percentage of defectives. This conclusion agrees well with the expectation that cerebral underdevelopment is very often associated with a general constitutional inferiority. Defectives not only tend to be deficient in height and weight, but lack even more markedly the psychophysical capacity that should match their physical development. By using height and weight in conjunction with cerebral capacity, one is able to gather an indication of the relation between them. A low cerebral development may be of less importance when associated with a generally inferior bodily development. It is of more importance when associated with a very low psychophysical capacity or a high physical average. On the diagnostic summary card used in our investigation (See Figures 5 and 6), provision is made for the graphic representation, side by side, of each of the anthropometric measurements.

PART II—SECTION II

THE PSYCHOLOGICAL EXAMINATION

The Binet-Simon Scale

Despite its recognized limitations, the Binet-Simon scale is one of the most valuable instruments in mental diagnosis. Nevertheless, contrary to many expectations, it has not by any means enabled us to substitute purely objective for subjective standards in the recognition of mental defect. The attempt to define moronity in terms of Binet age has not been successful. Though 12 years per Binet may be the highest mental age of some undoubtedly feeble-minded in institutions, it has not yet been proved that many individuals who are below that limit cannot function satisfactorily in society. The truth is that eleven years mental age may be taken as being about the middle point of the intelligence range of high grade defectives. The individuals about that level are classed among the feeble-minded, not on account of poor intellectual attainment, but chiefly because of mental instability. In such cases a Binet examination is recognized as insufficient.

This being the case, many of the published statistics with regard to the number of mental deficient in gaols and reformatory institutions—statistics based on Binet ages and ranging from 100 per cent. of inmates defective downward—must be largely discounted. Similarly, estimates of the percentage of defectives in schools may need revision. It is probable that at least 2 per cent. of school children are defective, but it does not necessarily follow that they are individually the 2 per cent. that a Binet examination would class as feeble-minded. Wherever we attempt to fix the lower limen of normality by Binet standards alone, either a proportion

of feeble-minded will be found above it or a number of normals will be found below it.

Criticism of the Binet Scale

Some of the chief criticisms of the Binet-Simon scale may be summarized as follows:—

1. The results are materially affected by the child's previous training.
2. It grades too highly the glib-tongued child and conversely rates unfairly the child with less language facility than motor ability. (Ayres, Healy, Porteus.)
3. The mental functions tested by the scale are, in general, very similar in nature (Bronner.) In other words, it measures predominantly one kind of ability. An interesting proof of this statement is the fact that Doll has abbreviated the scale by selecting two tests for each year, and allowing six months' credit for each test passed. This abbreviated scale has been found to correlate very highly indeed with the full scale. Coefficients as high as .95 have been obtained.
4. The scale is not decisive in the very cases where there is most doubt as to the mental status. (Fernald, Wallin.)
5. It is too narrow as regards the range of capacities tested. Some capacities most essential to social efficiency are not examined at all. "The Binet scale may not reveal what might be of vast importance for society to know concerning the individual." (Healy.)

Who Is to Undertake Diagnosis?

A large amount of criticism such as that by Wallin (35) seems to be directed, not so much against the scale itself but against those who use it illegitimately. He is right in his contention that the scale was never intended to carry the full burden of diagnosis. Mental defect is not wholly a psychological problem; it has its medical aspects as well, and we are in full agreement with those who emphasize the fact. Mental diagnosis requires special training and experience and should not be attempted by unqualified persons.

Value of Binet

Both the value and limitations of the Binet-Simon scale have been excellently set forth by its own authors as the following extracts from their writings show:—

"Our scale of intelligence gives the actual level of the intelligence without analyzing it and without informing us about the mentality. . . .

"It is an error to pretend that the scale alone is sufficient to enable us to know the character of the children; in reality, it is made to aid observation, to complete and to control it, but by no means to replace it. . . .

"The scale is not an automatic registering machine which announces a decision regarding a child's mental status with mechanical accuracy."

The essence of the value of the Binet scale is its practicability. Some

most unwieldy schemes of mental examination have been devised, and these contain many unstandardized tests. If applied with the care and exactitude their authors recommend, they would require weeks of testing, and since there are no tests which are absolutely diagnostic or possessed of mechanical accuracy, diagnosis would be no further advanced.

We have already referred to Healy's classification in which he bases diagnosis on the observations of the individual's social capacities combined with the findings of accredited age tests. Amongst these mental tests the Binet-Simon scale will continue to take premier place.

Standardization of the Binet Scale

Increased value has been given to the B.-S. scale by the modifications made by American investigators. The most valuable revisions are those by Goddard (36) and Terman (37). The Stanford Revision (Terman's) is already sufficiently well known as to need no further description, whilst Goddard's pioneer work has won widespread recognition.

The difficulty of standardizing these revisions has been complicated by the effect of social environment on the development of children. Yerkes and Bridges (38) in the elaboration of their Point Scale, have begun the work of establishment of norms of performance in different social grades. Terman sought to avoid the difficulty by limiting as far as possible his subjects to the one social grade. He states that the children examined by his revision were drawn from schools in middle class areas in American cities. "The method was to select a school in a community of average social grade."

In order to test the standardization of the Stanford Revision under Australian conditions, one of us (Porteus) undertook the examination of a group of 1000 school children, a group equal in number to Terman's. Our children, however, were not of equal social grade to Terman's subjects. About two-thirds were drawn from schools in lower class areas in Melbourne. At the same time these children cannot be compared to the children of lower class slum areas in larger cities abroad.* The remaining third comprised children attending a middle class school and a small group of rural children. Hence the differences between our results and Terman's may be partly attributed to the different social grade of our subjects.

In gauging the standardization of the tests we have adopted a similar method to Terman's, viz., we have compared the average mental with the average chronological age of each age group. Terman uses the median instead of the average, but with a large number of cases and an ordinary distribution there should be very little difference.

*Melbourne's population is about 800,000.

Table No. 21

BINET-SIMON TESTS. STANFORD REVISION. MENTAL AND CHRONOLOGICAL AGES
COMPARED. 1000 Cases. (Porteus.)

CHRON. AGE.	No. of Cases	Average Mental Age	Difference Mental and Chron. Age
5.5 yrs.	30	6.24 yrs.	+ .74 yrs.
6.5 "	71	7.3 "	+ .8 "
7.4 "	124	7.7 "	+ .3 "
8.4 "	152	8.5 "	+ .1 "
9.4 "	140	9.1 "	— .3 "
10.4 "	119	10 "	— .4 "
11.5 "	114	10.5 "	—1.0 "
12.5 "	127	11.3 "	—1.2 "
13.4 "	98	12.8 "	— .8 "
14.3 "	25	12.5 "	—1.8 "

At first sight the tests would appear to be too easily graded for the lower years and to be too difficult for the upper years. As regards the upper years the apparent retardation of children at 14 years of age probably represents the true state of the case. The school-leaving age is for Victoria 14 years, so that the presumption is that the children remaining at school after that age are mentally retarded children. The average mental age after 12 years is also affected by the elimination of the brighter pupils who leave the primary schools to attend technical schools and colleges. With regard to the relatively high average mental ages of the children at ages 5 and 6 years, the social factor must be taken into consideration. These were nearly all children of lower social grade. The average intelligence quotients of the city children below the age of 11 years can be seen in the following table.

Table No. 22

INTELLIGENCE OF CITY CHILDREN

AGE GROUP	No. of Cases	Average I. Q.
5 years	26	113
6 years	65	112
7 years	114	104
8 years	131	99
9 years	100	95
10 years	74	96

Terman states that he found the performance of lower class children to be on the average about 7 points below that of children of better social grade. Probably this opinion was not based on a point by point comparison of records at each age level. It will be seen that our young city children found the tests somewhat too easy, and that it was only at 8 years that the average of the city children tended to fall below 100 I. Q. This superiority of the city child at the lower age levels is, we believe, more apparent than real. It is largely due to the tests at these levels favoring the mentally alert, glib-tongued children. There is a very large number of questions in the tests below 9 years, which examine memory in some form, either immediate or remote, and memory, as Binet himself remarked, is "a great simulator of intelligence." Many other tests in these years are dependent on facility in the use of language. Hence, the young city child, having so many points of social contact to sharpen his wits and to give him a superficial brightness, far excels his country cousin.

If, however, social grade has not the effect indicated, then we must conclude that the tests for the lower years are too easily graded. So, too, if city children of lower social class are not retarded in intelligence after middle childhood, then the tests for the upper years are too hard.

In Table No. 23 the distribution of I. Q.s found by Porteus may be compared with those published by Terman. The close agreement of the percentages of the very dull and the super-intelligent children will be noted. The Australian results show the middle point of the distribution at a point somewhat below 100 I. Q.

This, as shown above, may be due to the poor records of the rural children in the lower years and of the lower class city children in the upper years.

Table No. 23

AMERICAN AND AUSTRALIAN CHILDREN COMPARED. (Porteus, 1916.)
(Terman, 1000 Cases.) (Porteus, 1000 Cases.)
Distribution by Binet Intelligence Quotients.

PERCENTAGES		I. Q.	PERCENTAGE		I. Q.
Terman	Porteus		Terman	Porteus	
1%	1.1%	70 or below	1 %	1.3%	130 or above
2%	2.2%	73 " "	2 %	2 %	128 " "
3%	4 %	76 " "	3 %	3.1%	125 " "
5%	5.5%	78 " "	5 %	3.8%	122 " "
10%	15.5%	85 " "	10 %	8.7%	116 " "
15%	23.2%	88 " "	15 %	13.1%	113 " "
20%	30.2%	91 " "	20 %	18.5%	110 " "
25%	33.1%	92 " "	25 %	22.6%	108 " "
33%	43.1%	95 " "	33.3%	26.9%	106 " "

On the basis of these results a classification of children according to their intelligence may be tentatively made. As previously explained, the exact number of feeble-minded is not obtainable from such a table.

One per cent. (I. Q.s 70 or below) are distinctly subnormal but are not, necessarily, all feeble-minded, although Terman would place the lower limen of normality at an I. Q. of 70.

An additional 2 per cent. are very dull indeed. These have I. Q.s from 70 to 75. Some of these are undoubtedly feeble-minded.

An additional 12 per cent. may be classed as being dull, and this group will include many of the mentally unstable. Their I. Q.s are 85 and below. For all these children, clearly retarded in development, the educational system must make special provision either by means of special schools or ungraded classes or by trade schools.

An interesting comparison may be made between our figures and those obtained by other investigators. Burt (39) found that 4.2% of school children in the borough examined (London) were backward by 3 years or more. Of all children over 5 years and under 15, 9.5% were backward by 2 years or more. The number retarded one year or more amounted to 35% in all. Assuming that those retarded 2 years or more should be classed as dull, then Burt's and Terman's results are in close agreement. Goddard (40), however, found 3% to be 4 or more years retarded. An additional 15% he classed as dull. Hence, our percentage of dull children, viz., 12%, comes between Terman's (10%) and Goddard's estimate.

With regard to the very intelligent children, our results accord well with Terman's. 3.1% of our children have I. Q.s above 125, as against Terman's 3%. Goddard records 4% two or more years advanced.

PART II—SECTION III

PSYCHOLOGICAL EXAMINATION—PORTEUS TESTS

The Mentally Unstable

Binet, in his characterization of the feeble-minded, distinguishes one type by the term "ill-balanced." Mental instability is certainly a characteristic of a large number of mental defectives. In some it is so marked that it is the most pronounced clinical feature. For such individuals the term "unbalanced" would almost be appropriate. Burt has described them as follows:—

"Eventually it will probably be necessary to recognize a further group of children, the 'unstable' children whose mental insufficiency primarily affects, not their intelligence or scholastic ability, but rather their impulses, instincts, emotions, moods and moral self-control, in a word, their temperament or character."

Tredgold (2) thinks that in the majority of feeble-minded persons mental defect is accompanied by more or less mental instability. These individuals constitute the gravest social danger. Being industrially inefficient, they are more likely to find occupation in crime. He considers that mental instability, though it may arise through environmental causes, is often inborn.

It is important to recognize that in such cases it is the instability that is inherent and not the educational backwardness with which it is so often associated. In this connection Burt remarks:—

"From the ranks of the backward children are recruited the majority

of the most undesirable members of society. . . . In early years they come under special notice, primarily because they are educationally backward. In addition, they may show troublesome moral, emotional or physical peculiarities. These are probably the cause of the backwardness at school and will probably prove the cause of delinquency in later years. For the rest, out of school they are fairly intelligent, often cunning in action, and plausible in speech."

For such cases it is evident that the intellectual retardation not being the salient feature of their psychology, tests such as the Binet only serve to demonstrate the intellectual backwardness. What is evidently required to supplement the Binet examination are tests of other capacities important for social sufficiency. These social capacities are in the main dependent on the ability to control impulsive action. In a word, we wish to test self control.

Socially Important Capacities

One of the most important factors in the development of inhibitory power is the habit of forethought. Preconsideration, a weighing of pros and cons, would, in persons of ordinary intelligence, prevent serious mistakes in judgment or policy. When we find in association with an impulsive temperament a weak intelligence, then we have the typical social inefficient.

Terman (37) states:—

"Morality depends upon two things, (a) the ability to foresee and to weigh the possible consequences for self and others of different kinds of behaviour; and (b) upon the willingness and the capacity to exercise self restraint."

Healy (4) mentions judgment and foresight amongst the qualifications which make for social success. Of foresight and planfulness he says:—

"It was Thorndike who long ago said to us that if weakness in any one particular ability were, *a priori*, to be most likely to stand often at the root of criminalism, it would be the lack of foresight." Goddard goes so far as to make planning capacity the touchstone of normality. After enumerating the normal capabilities of the highest grade of moron, he makes this reservation as to their mentality—"only are unable to plan anything."

Another important capacity, a lack of which has been made one of the defining marks of the feeble-minded, is prudence. This is not wholly dependent on foresight. Many an excellent plan has been ruined by imprudence in its execution. Hence we require tests of executive capacity. Some individuals are, however, over-prudent. They are so fearful of

failure that all their actions are tinged with irresolution. Autocriticism is in their case pushed to such extremes that they become convinced of their own inability to compete with their fellows on equal terms. This self-distrust may develop to such a degree as to render the individual socially inefficient. Where this sense of dependence is apparently ineradicable and is evinced from an early age, the individual may well be designated "psychoasthenic." In adolescence this condition shades off into insanity.

Ability to Profit by Experience

Temperamental failings are of course not limited to the feeble-minded. Impulsiveness and careless behaviour are characteristic of many normal children, but in one respect these differ widely from the feeble-minded. The normal individual has the capacity to profit by experience, which the mental defective lacks. The everyday virtues of care and prudence, the ability to foresee the probable results of a certain line of action, the capacity for inhibition are subsumed, in popular language, under the heading of "common sense," which is recognized as the salient deficiency of the mentally unstable. People who lack this complex of capacities are said "to have no judgment," to be "silly" or "irresponsible." If, as we believe, this capacity for the control of instinctive behaviour is dependent on the development of the newest cell layer of the brain (the supra-granular layer), then the prevalence of moral instability is thus accounted for, because what is phylogenetically recent is necessarily more prone to ontogenetic disturbances of function.

Power of Adaptation to New Situations

The ability to adjust oneself successfully to new situations is very largely dependent on the capacities of foresight, prudence, and the ability to profit by experience. "The mentally deficient person fails to adjust himself adequately to life's ordinary environment because he lacks foresight to anticipate, mental alertness to realize, and common prudence to deal with a situation."—(42)

This power of successful adjustment is so important that it forms the basis of the most satisfactory definitions of intelligence. One of the most widely quoted is that by Stern (41):—

"The general capacity of an individual consciously to adjust his thinking to new requirements through general adaptability to new problems and conditions of life."

Tests for Socially Valuable Capacities

The question now arises whether it is possible to evaluate by means

of tests these most important capacities. This is admittedly a very hard task. Healy states that "it appears to be a very difficult matter to check up with accuracy the powers of foresight, so much do they vary in different fields of thought and action. Certainly, foresight has much to do with planfulness, and the latter can be tested in various ways."

Tests of self control will be even more difficult to devise. Just as in the case of educational disability, we may have an all round weakness or a particular disability in one direction. A man may show commendable self restraint with regard to one instinct and in regard to another, as for instance, the sex impulse, be pitifully weak in self control.

We cannot, of course, measure the strength of instincts in individuals, but as regards inhibition we may use the social criterion. Social restraints and sanctions operate very differently with regard to the indulgence of instincts; they may allow a freer rein in one direction than another.

In behaviour there is a point at which prudence, either through the fear of punishment or the restraint of public opinion, begins to operate. If an individual oversteps this limit, he does so either because he cannot forecast the results of his action, or because an impetuosity of temperament carries him too far before he has the opportunity to reflect, or because he is deliberately anti-social. If social inefficiency is the result of either of the first two causes, then the defective control is of such a grave nature that it will in all probability be reflected in the individual's reaction to every situation in which prudence and foresight are called for. In other words, if the tendency towards imprudence in behaviour is so pronounced as to render the individual socially inefficient, or potentially so, the specific weakness will usually be accompanied by a generally weak inhibitory power which can be demonstrated by tests, even if those tests deal with a limited field of action.

The greatest value of tests of this nature is from the negative standpoint. We cannot argue that success in the tests is always indicative of ability for social adjustment. However, if the subject in a simple situation displays a very poor capacity for self-restraint and lack of foresight, then it is fair to conclude that in the far more complicated situations of everyday life he is unlikely to exhibit these saving graces. In other words, failure in the tests is more significant than success.

Some Requirements of Tests

Tests of this nature, if they are to find a place in mental diagnosis should as far as possible fulfil some requirements.

First of all they should supplement the Binet examination by examining the capacities which the latter does not test sufficiently. In the

second place, their value will be in converse relation to the independence of the mental functions involved. If in a single test two poorly correlated mental functions are involved it would be extremely difficult to say which function was at fault if failure resulted. Many puzzles might be exceedingly useful as tests of planning capacity except that in many cases a highly specialized manual dexterity is also involved. Others again call for a high development of the power of retaining in memory visual representations of situations—memory for place and form. Under this heading come the games of chess and draughts, the latter of which Fernald and Healy (43) think to be of value in testing foresight and prudence. Both these games require the special memory capacity mentioned above. The skilful player must have the ability to keep in mind very many possible combinations of the pieces on the board. This visual memory for position is not necessarily correlated highly with prudence, nor with the tendency to inhibit impulsive action. The most skilful chess player is not necessarily the most deliberate one. The foresight required in chess is of a very special kind and not much akin to that needed for the problems of behaviour of everyday life. Hence failure, except it be always due to an easily observed impulsiveness, is not always indicative of potential social insufficiency. Foresight is not, in these games, tested in such simple situations as to make failure significant. Previous practice, too, is a factor not easily reckoned with. This is a third consideration in the devising of tests. The power of ready adaptation can only be estimated by observing the child's response to a new situation. Successful adaptation is, however, largely dependent on the individual's ability to profit by past experience. Hence, the tests, whilst testing the same capacities throughout should be capable of being graded to form a scale. The advantages of this are obvious. The test material remaining the same throughout in nature, though differing in complexity at the various age levels, will be free from the objection that it is not exhaustive. Interesting evidence as to the phases in development during childhood of the capacities tested will be provided. Further, the power of the individual to improve with the practice afforded by the tests themselves may be observed.

A series of tests of a homogeneous nature must have great advantages over isolated tests. Many of the latter type are standardized for a given year, but we have no means of judging the performance of a child some years below this age.

Several tests have been designed to prove planning capacity. They, too, though excellent in many ways, do not allow the child to see his mistake until the last step in construction is reached. A trial and error method in such tests is often fruitful of success. Finally, it would be

extremely difficult to standardize these tests to suit many age levels. Other puzzle-tests, designed to test ability to plan, call for a considerable amount of manipulative skill.

The Porteus Maze Tests

Taking into account the above considerations, it appeared to Porteus that the printed maze provided the best possible material for satisfactory tests for aiding mental diagnosis. The habit of preconsideration would be apparent in the individual's method of attacking the problem, or conversely his tendency to impulsive action. Planning capacity also could be observed, not as regards mechanical construction certainly, but with regard to the mapping out a course of action of the simplest nature—a test more akin, it was thought, to the kind of foresight involved in social adjustment. An additional advantage lies in the fact that the test is new to the child's experience, so that the influence of previous practice is eliminated. By gradually increasing the complexity of the maze designs tests can be standardized for each age level. The ability of the child to profit by experience may be gauged by means of the method of allowing repeated trials. The fact that the scale tests the same capacities throughout is of value since the lower year tests provide practice for the tests following, so that the child may through its experience effect an improvement in method of attacking the tests. Further, no highly specialized ability, such as manual dexterity, is involved in the actual working of the tests. No special memory capacity is called for. A preliminary survey of the tests is advantageous, but there is no need to memorize the whole course to be pursued, as the problem can be best attacked piecemeal. The individual is faced again and again with a similar problem—shall he turn to the right or left—the right decision being dependent on the exercise of a little prudence in stopping to consider, and of a little foresight in being able to see what the results of the proposed action will be. In working through the whole of the mazes from six years to thirteen years the individual is confronted with a similar problem upwards of forty times, so that if he has any capacity to profit by experience he has excellent opportunities for displaying it. An error committed is almost immediately apparent, so that the individual, by seeing his own mistake, may, if he has it in him, make a readjustment of his methods.

The Arrangement of the Tests

Some difficulty was at first experienced in devising tests for the lower years. These tests had necessarily to be of the simplest nature and the directions given had to be such that the very young child could understand and follow.

Success is also bound up with the child's will to succeed, for if genius

be an infinite capacity for taking pains, then mental deficiency is distinguished by an infinite incapacity in this respect.

These lower-year tests were arranged almost wholly on the records of defective children, with comparatively small groups of normals as control groups. It was, therefore, interesting to note the experience of other observers working with normal children. A record of the results of the application of the Porteus tests to kindergarten children is given by Miss Shaw (44).

"A surprisingly correct view of individual differences can be gained through such a test. The slow child who habitually leaves his work half done, the child who is prone to misunderstand spoken directions, the child who makes careless mistakes but quickly corrects them himself, the child who improves with practice, the child who tires or loses interest and hence does worse instead of better in a second trial,—all these and many more types that we all know, reveal their everyday traits in this five-minute test as clearly as in a year's work."

Opinions such as the above, together with extensive subsequent experience, justified the early decision to retain the lowermost tests in their original form although the age standardization and the scoring were altered on the basis of more reliable norms. Detailed description of the tests is unnecessary, as this may be found in the various articles in which work with the test has been reported.

Standardization of the Porteus Tests

The 1916 survey previously mentioned gave an excellent opportunity to test the standardization of the tests with the revised method of scoring. As was the case with the Binet-Simon tests (see Table 21) the average age of each age group was compared with the average mental age. The group of children tested was the same thousand whose B.-S. scores have been previously given.

Column No. 4 of Table 24 shows the difference between the test age and the chronological age. It is evident that the tests were too easy for the first three years shown in the table and too difficult for years eleven, twelve and thirteen. The numbers at the five and fourteen year levels are small and, as was the case with the Binet, little significance should be attached to the results for the latter year because of the elimination of the brighter pupils from school before this age. An additional reason for the lower scoring in the upper years was that the test series ended at thirteen years. A number of children at this age would undoubtedly have passed higher tests had such been provided. Consequently, as far as standardization is concerned, only the results up to twelve years should, in all

probability, be considered. A comparison of the Binet and Porteus averages is given in Table No. 25.

Table No. 24

**PORTEUS TEST AGES AND CHRONOLOGICAL AGES COMPARED.
BINET AND PORTEUS AVERAGES COMPARED**

Chron. Age	No. of Cases	Average Test Age	Difference Chron. and Test Age	Binet Age	Difference Binet and Porteus
5.5 yrs.	30	7 yrs.	+1.5 yrs.	6.24	P+ .76
6.5	71	7.7	+1.2	7.3	P+ .4
7.4	124	8.2	+ .8	7.7	P+ .5
8.4	152	8.6	+ .2	8.5	P+ .1
9.4	140	9.1	— .3	9.1	0
10.4	119	9.8	— .6	10	B+ .2
11.5	114	10.5	—1.0	11.5	0
12.5	127	11.	—1.5	11.3	B+ .3
13.4	98	12.	—1.4	12.8	B+ .8
14.3	25	11.7	—2.6	...	..

Table No. 25

BINET AND PORTEUS AVERAGES COMPARED. (Porteus, 1916.)

Chron. Age	Binet Age	Porteus Age	Difference-Binet & Porteus
5.5	6.24	7	Porteus + .76
6.5	7.3	7.7	Porteus + .4
7.4	7.7	8.2	Porteus + .5
8.4	8.5	8.6	Porteus + .1
9.4	9.1	9.1	0
10.4	10	9.8	Binet + .2
11.5	10.5	10.5	0
12.4	11.3	11	Binet + .3
13.4	12.8	12	Binet + .8

It will be seen that the average difference for all years is not great, amounting to about one-third of a year. If Terman's revision is correctly standardized, then the Porteus tests are not much misplaced as regards their age levels. If, however, the differences between the mental and chronological ages in the case of the Binet are due to errors in standardization, then the Porteus tests repeat these errors in somewhat exaggerated form.

Table No. 26
BINET-PORTEUS CORRELATIONS.

Age	BOYS, 476 CASES			GIRLS 467 CASES		
	No. of Cases	Correlation (Pearson r)	P.E.	No. of Cases	Correlation	P.E.
6 yrs.	43	.42	.085	28	.48	.098
7 "	63	.24	.08	63	.57	.057
8 "	76	.39	.066	76	.41	.064
9 "	63	.56	.058	77	.75	.034
10 "	49	.61	.066	70	.61	.051
11 "	60	.6	.056	50	.56	.066
12 "	66	.55	.058	61	.46	.068
13 "	56	.39	.076	42	.63	.063

Comparison with Binet Results

The close agreement shown in Table No. 25 between the Binet and Porteus averages may not of course hold good in individual cases. As regards a general agreement, over 70 per cent. of the children tested by the Porteus scale within one year of their Binet age.

Table No. 26 shows the correlations found at each age level for each sex separately.

Sex Differences—Binet and Porteus Tests

The boys' correlations range between .24 and .61, whilst the girls' range is between .41 and .75. Apparently the boys show a greater amount of variation between the results of the two tests than the girls. At only two years (11 and 12) do the boys show a higher correlation than the girls. These results appear to mark well defined differences in sex performance. The average test age at each age level may be compared in Table No. 27.

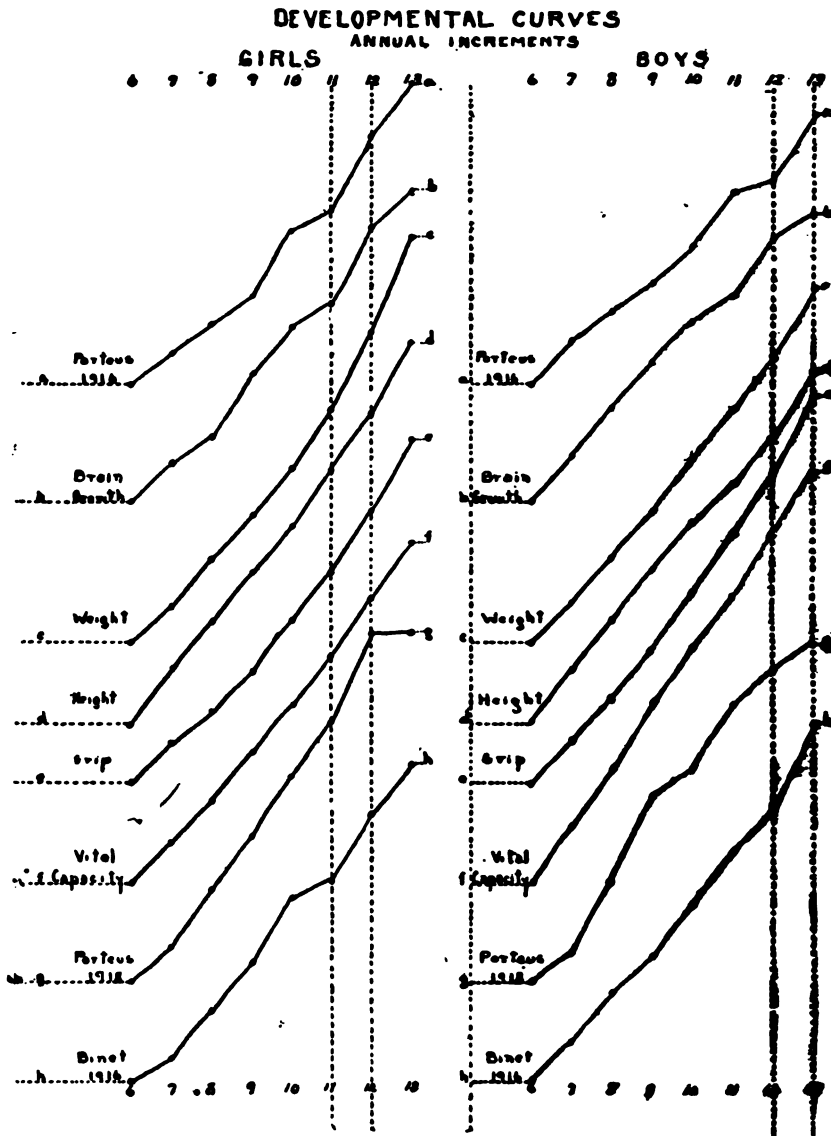
The superiority of the boys' average performance is well marked in every year up to and including year eleven. At 12 years of age, however, the girls make a remarkable improvement. In the section dealing with grip measurements it was shown that this period was the one in which the greatest increment of psychophysical capacity took place. It therefore appears to be a most favorable period in the girl's development, both physically and mentally. As regards increase of brain capacity, a reference to the girls' percentiles (Female formula Table 8) will demonstrate the same fact. From the 12th to the 13th year the girls' increment of cubic capacity (mean) is 32cc. as against only 9cc. for the twelve months

Table No. 27

SEX DIFFERENCES IN PERFORMANCE. PORTEUS TESTS

1000 Cases. 1916 (Porteus)						1255 Cases. 1918 (Porteus)						198 Cases. 1919 (Foote)					
Chron. Age	No. of Cases	Boys' Test Age	No. of Cases	Girls' Test Age	Diff.	No. of Cases	Boys' Test Age	No. of Cases	Girls' Test Age	Diff.	No. of Cases	Boys' Test Age	No. of Cases	Girls' Test Age	Diff.		
5.5	16	7.27	16	6.63	B .64												
6.5	43	7.92	28	7.54	.38	64	7.15	64	6.91	B .24	52	7.32	46	6.53	B .79		
7.5	63	8.57	63	7.98	.59	75	7.62	75	7.44	.18	45	7.96	55	7.3	B .66		
8.5	76	8.95	76	8.39	.56	78	8.66	67	8.32	.34							
9.5	63	9.41	77	8.86	.55	86	9.92	79	9.14	.78							
10.5	49	9.94	70	9.76	.18	75	10.29	91	10.01	.28							
11.5	60	10.82	50	10.1	.72	94	11.35	84	10.81	.54							
12.5	66	10.9	61	11.3	G .4	95	11.88	96	12.16	G .28							
13.5	56	11.97	42	12.07	G .1	56	12.2	76	12.11	B .09							
14.5	13	11.79	12	11.67	B .12												

Figure 4



previous. From 11 years to 12 years the girls make the greatest gain of any annual period between 6 years and adult life.

In speaking of the period in this way it should be remembered that "from 11 years to 12 years" actually means from 11.5 to 12.5 years. The annual increments for both boys and girls in all measurements investigated are given in Figure 4.

Sex Differences in Binet Results

An interesting comparison may now be made as regards sex differences in performance per Binet. It will be seen by Table No. 28 that, on the whole, these differences between girls' and boys' performances are not so marked as in the Porteus tests. In three years the girls equaled the boys, their relative improvement at 12 years again being marked. It is noteworthy that Terman concludes on the basis of his results that the intelligence of girls does not differ materially from that of boys.

Table No. 28
SEX DIFFERENCES—BINET-SIMON TESTS.

Chron. Age	Boys	Girls	Difference
	Average Test Age.	Average Test Age	
5.5 yrs.	6.45 yrs.	6.03 yrs.	Boys + .42 yrs.
6.5 "	7.27 "	7.25 "	
7.5 "	7.84 "	7.63 "	Boys .21 "
8.5 "	8.65 "	8.34 "	Boys .31 "
9.4 "	9.16 "	9.04 "	Boys .12 "
10.4 "	10 "	10 "	
11.5 "	10.8 "	10.3 "	Boys .5 "
12.4 "	11.3 "	11.3 "	
13.4 "	12.7 "	12.07 "	Boys .63 "
14.3 "	12.4 "	12.3 "	Boys .1 "

Examination of the Tables shows that the greatest annual increment of intelligence, as measured by both the Binet and the Porteus tests, took place in the period from 12.4 years to 13.4 years in the case of the boy. Both tests agree also in showing the girls' greatest increase during the previous year. It is interesting to note that these facts again agree with the phenomena of growth of head capacity. Comparing the medians, (or 50 percentiles) of the State School boys (Table 6) it is seen that from the thirteenth to the fourteenth year, (ages 12.5 to 13.5) is a period of relatively great increase. Hence it is quite reasonable to conclude that the periods of mental and physical acceleration do tend, on the average, to coincide.

Revision of the Porteus Tests

Using the information tabulated in the foregoing tables, Porteus was enabled to make a tentative revision of the scoring previously adopted in the tests. The old 3-year test was allowed to remain as a practice design and the tests for the succeeding four years were put down one year in value. New tests for six and seven years were then interpolated in the series. A slight modification was made in the form of the ten year test, and the old 13-year test was assigned to 14 years. In addition, four trials were allowed in the last two tests of the series instead of three as formerly. The same rule regarding deductions for repeated trials was adhered to in this revision as formerly.

The tests were then applied to two large groups of State School children drawn from districts as widely separated socially as possible. The first group might be considered middle class children, and the second, lower class, being drawn from schools in an industrial suburb. The numbers in each group were respectively 585 and 670. In all 1255 children were examined, 623 boys and 632 girls.

Table No. 29 gives the results for the whole group. The standardization may be judged by comparing the average chronological and test ages for each year group.

Table No. 29
STANDARDIZATION OF PORTEUS TESTS (REVISED)
1255 Cases—(Porteus 1918)

Chron. Age	No. of Cases	Average Test Age	Difference Chron. & Test Age
6.5 yrs.	128	7.03 yrs.	+ .53 yrs.
7.5 "	150	7.57 "	+ .07 "
8.5 "	145	8.5 "	0.
9.5 "	165	9.55 "	+ .05 "
10.5 "	166	10.14 "	— .36 "
11.5 "	178	11.1 "	— .4 "
12.5 "	191	12.02 "	— .48 "
13.5 "	132	12.15 "	—1.35 "

According to the above results the test for 6 years is still a little easy. The 14-year test is apparently a little over a year above the level of the 13-year old children. Unfortunately there were not sufficient fourteen-year old children available for testing, and those who were available could not be considered average in intelligence. Judging by the above results, it is probably fairly standard for fourteen years. On the whole

the standardization appeared to be considerably improved by the revision of the scoring conditions.

Influence of Social Grade

When the records are examined in separate social grade groups, some interesting facts are brought to light. Table No. 30 shows a comparison of an average test age for each age group in the different social strata. The sex differences are also given for each group of children.

Table No. 30

SOCIAL CLASSES COMPARED.				REVISED PORTEUS TESTS.		
Chron. Age	LOWER CLASS		Sex Diff.	MIDDLE CLASS		Sex Diff.
	Boys' Aver. Age	Girls' Aver. Age		Boys' Aver. Age	Girls' Aver. Age	
6.5	6.9	6.7	B. .2	7.45	7.2	B. .25
7.5	7.3	7.35	G. .05	8	7.6	B. .4
8.5	8.6	8.38	B. .22	8.8	8.27	B. .53
9.5	9.53	9.13	B. .4	10.42	9.15	B. 1.27
10.5	9.96	10	G. .04	10.62	10.04	B. .6
11.5	11.5	10.7	B. .8	11.2	10.95	B. .25
12.5	11.91	12.12	G. .21	11.86	12.2	G. .36
13.5	12.41	12.41	Equal	12.	11.85	B. .15

By reference to the fourth and last columns of Table No. 30 it will be seen that the boys' advantage over the girls is more marked in children of middle class than in those of lower social grade. In the case of the latter, the girls held an advantage in three years and were equal with the boys in another year. With the children of middle class, on the other hand, the boys had a marked advantage in every year up to 12 years.

Table No. 31

SOCIAL GRADES COMPARED.		DIFFERENCES IN PORTEUS TEST PERFORMANCES	
Chron. Age	Boys		Girls
6.5 Yrs.	Middle C.	.55	Middle C. .5
7.5 "	"	.7	" .25
8.5 "	"	.2	Lower C. .11
9.5 "	"	.09	Middle C. .02
10.5 "	"	.68	" .04
11.5 "	Lower C.	.3	" .25
12.5 "	"	.05	" .08

The differences in test performance due to social grade are better exhibited by comparing each sex separately as in Table No. 31. Owing to the elimination of better class boys and girls at or about 13 years the comparison has not been made at this age. The method adopted for this table has been to take the data of Table No. 30 and to compare the average performance at each age level. The prefixing of the name of the class shows with whom the advantage lay.

It is evident that the middle class boys have an advantage up to eleven years of age, the average superiority amounting to about .6 of a year. For these years it would probably be about correct to reckon the median performance of boys of lower class to fall about four points below that of middle class boys. The superiority of the lower class boys at eleven years and twelve years is probably due to the earlier occurrence of the pre-pubescent period in boys of this class. In girls the average advantage due to social grade is so slight as to be practically negligible as far as standardization is concerned. The occurrence of periods of accelerated growth in capacity may be shown by an examination of the data of Table No. 30.

It will be seen that in the case of lower class boys the greatest annual increment of capacity comes at the periods from 7.5 to 8.5 years and a pre-pubescent increase at from 10.5 to 11.5 years. In the better class boys this first period of accelerated growth in capacity as measured by the tests is apparently delayed a year. The second period appears to be delayed somewhat. With girls of both classes the period of greatest increase falls at 12 years.

The general conclusion that these tables appear to warrant is, that the only allowance in standardization that should be made for the factors of sex and social grade is for boys of better social grade. It may be necessary to consider their average or median I. Q. as being three or four points above girls of the same social grade and the same amount above children of both sexes of lower grade. This allowance need only be made for children who have not reached the pre-pubescent period.

It has been necessary to set out these results in such detail so as to render explicable fluctuations in correlations and also certain differences in published results wherein sex and social grade have not been allowed for.

Porteus Tests—Relation to Intelligence

The relation of the Porteus tests to general intelligence has already been dealt with. It was expected that the improvement of the standardization of the tests would result in the raising of the correlation coefficients with the Binet. The opportunity of testing sufficiently large numbers of children by the full Binet and the revised tests has not yet

occurred. The revised tests have, however, been applied by Porteus to a large group of children and the results correlated with the mental ages as obtained by the abbreviated Binet Scale arranged by Doll at Vineland.

For this purpose the former selected a special group of children, viz., those whose head capacities fell below the 10 percentile of their age group, and those who were above the 90 percentile. Consequently, his cases included more than the average of abnormal children. The Pearson correlation between the I. Q.s by the two series of tests was .77 with a negligible probable error.

Porteus Tests and School Progress

In our method of diagnosis account is taken of the school progress of the child. But we do not attach the importance to the pedagogical tests that some observers do. Especially doubtful in value for mental diagnosis is the evidence provided by the school standing of the child. The recent attention that has been directed to the problem of school retardation has resulted in all sorts of schemes for grade promotion, so that the position of the child in school grade may be but little indication of his potential social sufficiency. Unfortunately in the case of the mentally unstable child with very fair educational attainments,—that is to say in the cases where aid in diagnosis is most required—the educational criteria fail us. At the same time for the majority of cases school standing has some diagnostic value.

Table No. 32

PORTEUS TESTS. CORRELATIONS WITH GRADE STANDING. (C. Q.s) 1247 Cases

Chron. Age	Boys (617)			Girls (630)		
	No. of Cases	Correlation r.	P.E.	No. of Cases	Correlation r.	P.E.
6.5 yrs.	63	.42	.07	64	.33	.075
7.5 "	75	.31	.07	74	.27	.073
8.5 "	78	.34	.067	67	.41	.068
9.5 "	84	.4	.062	79	.44	.061
10.5 "	74	.46	.06	91	.39	.06
11.5 "	93	.36	.061	83	.47	.058
12.5 "	94	.18	.068	96	.60	.044
13.5 "	56	.33	.08	76	.45	.062

The correlations of Porteus tests with school standing are given in Table No. 32, the latter being estimated by means of the class quotient

(C. Q.) or educational ratio, as it is sometimes called. This is arrived at by dividing the grade age by the chronological age and multiplying by 100. The class ages are for Grade I, 6 to 7 years; Grade II, 7 to 8 years, etc.

The higher correlations found between the tests and class standing in the case of girls at the ages 11, 12, 13 years illustrates the closer relation of the tests to intelligence in their case. It will be remembered that a somewhat similar result was observed in the correlations between the Binet and Porteus tests.

PART III

DIAGNOSIS AND THE INTERPRETATION OF TESTS

Social Inefficiency

Having reviewed the evidence for the validity of the separate tests used in our method, it remains for us to show how their results are to be interpreted and combined for diagnostic purposes. We have already indicated our approval of Pearson's dictum, that it is the detection of the potential social inefficient which is the chief concern of mental diagnosis. Society is no less injured by the mentally unstable, than by the intellectually feeble-minded. Many investigations go to prove that it is the dull and backward, the border-line cases, the mentally unstable, and the physically and constitutionally inferior children, who ultimately swell the ranks of the criminal, the vicious, and the industrially incompetent. We believe that, in the great majority of instances, these children may be detected by our examination method. In view of the immense importance of the prediction, we cannot see why any more definite diagnosis than that of potential social inefficiency is called for in a first clinical examination. The determination of the predominant causes of the condition, whether intellectual retardation, mental instability, constitutional inferiority, etc., may be left in doubtful cases to further observation. To this end the great need of child-welfare is the provision of parental or observation schools, which should serve as clearing-houses for control institutions for defective delinquents, for reform schools for delinquents not defective, and

for institutions for the feeble-minded. At such parental schools there should be a systematic study of the individual child, as regards all his reactions to educational, industrial, and social training. At the same time we believe that a clinical examination, such as we propose, will almost invariably indicate the cause of the condition. The essential point, however, is the prediction that the child will or will not be able to cope with the average conditions of social existence.

The Method of Diagnosis

We propose then to make this first diagnosis of potential social inefficiency on the basis of the verdict of the various parts of our method, which, taken separately, are not regarded as providing conclusive evidence, except in the obvious case where diagnosis is easy. The ability of the individual to get along satisfactorily in society is profoundly influenced by his education or learning capacity, by his practical ability along manual or industrial lines, by his temperament or disposition to adapt himself to social conditions, and by his physical make-up. Our method attempts to discover evidence of any general arrest or abnormality of brain development, which may underlie an insufficiency in all the mental characteristics above mentioned. In the next place it takes into account the bodily development which may be related to the cerebral; and thirdly it examines the individual's power of psychophysical adaptation, which is very important from the standpoint of the development of manual skill. Any deficiency here must also be interpreted in the light of the facts regarding the general mental and physical condition. Fourthly, intellectual retardation is gauged by the Binet examination. The fifth step is to obtain the rating by the Porteus Tests, which correlates highly with industrial and social capacity. Lastly, the child's history, as regards his adaptation to his home or school environment, should be taken into account. To complete the clinical picture, there should follow a thorough medical examination, which would show the number and importance of the physical defects.

The Method of Recording Clinical Results

In order to show the relation of the findings of the various steps of our method, the results are graphically represented by means of a psychogram.

Here at a glance may be seen the relation between the physical and mental characteristics of the individual, and their development as compared with the average development of normals of his own age. (See Figures 5 and 6.) On the psychogram are shown: One, the individual's brain capacity percentile, as obtained by a comparison with our tables;

two, his physical and psychophysical percentiles, as compared with Smedley's tables (republished by Doll, 32). The lines connecting these three points on the psychogram form an angle, the form and position of which have diagnostic significance. In the feeble-minded of the subevoluted type a common form of the record is an acute angle falling wholly below the horizontal line representing the fifty percentile or median of the three series of percentile tables, and having its apex at Physical Average (see Figure 5). Another form is an extremely obtuse angle where there is a high percentile of brain capacity, average physical measurements, and a low psychophysical average (see Figure 6). When this angle is compared with the angle formed by joining the points representing the mental records, a very good clinical picture is presented. Figures 5 and 6 represent the cards used by us in this investigation and the method of recording data. This card does not, of course, meet all the requirements of the proper study of an individual within an institution, but must be regarded as very comprehensive for the purposes of our survey. A full scheme for clinical study of an individual has been devised and is being used by one of us (Porteus). This has been described under the name of "A Standardized Information Record."*

Psychological Examinations

The application of our whole method presupposes the resources of a psychological laboratory. Mental examinations are, however, being carried on in very many places, so that it seems desirable to show how we may combine results of mental tests in such examinations. From the succeeding table it will be seen that educational capacity and the Binet test age correlate very highly. The Porteus Tests give higher coefficients with estimated degree of social fitness and industrial capacity. In the case of girls the difference in favor of the Porteus Test is pronounced. However, the average of the Binet and Porteus mental ages correlates better with both social fitness and industrial capacity than does either test taken singly. These correlations were obtained by Porteus with two groups of high grade feeble-minded and border-line cases in the Training School at Vineland. Independently of the mental examination, these children were ranked by the school principal and industrial director according to their educational attainment, industrial capacity and estimated degree of fitness to get along in the world. The latter rating took into account their dispositions and moral stability, as well as their industrial and educational capacities. The correlations, as given below, have been fully discussed by Porteus (42) on this evidence.

*"A Standardized Information Record," by S. D. Porteus. Publication of The Training School at Vineland, N. J.

FIGURE 5. ILLUSTRATIVE DIAGNOSIS CARD.

NAME. V. M. M.L.C.		SCHOOL.	
DATE OF BIRTH. 29/3/05.		AGE. 13 YEARS.	
BRAIN CAPACITY.		PERCENTILES.	
HEAD LENGTH.....	177MM.		
HEAD BREADTH.....	142MM.		
HEAD HEIGHT.....	129MM.		
CUBIC CAPACITY OF BRAIN.....	1241 CC.	13.	
PHYSICAL & PSYCHOPHYSICAL TESTS.		PERCENTILES.	
STANDING STATURE.....	140.0 CM.	10.	
SITTING STATURE.....	76.3 CM.	40.	
WEIGHT.....	37.8 K.	40.	
PHYSICAL AVERAGE.....		30.	
RIGHT GRIP.....	15 K.	3.	
LEFT GRIP.....	16 K.	8.	
VITAL CAPACITY.....	1600 CC.	3.	
PSYCHO-PHYSICAL AVERAGE.....		5.	
PSYCHOLOGICAL TESTS.		QUOTIENTS.	
BINET AGE.....	4 YEARS.	30.	
PORTERUS AGE.....	5 YEARS.	30.	
CLASS AGE.....	6 YEARS.	65.	
AVERAGE QUOTIENT.			

PERSONAL.

MISCHIEVOUS. EXCITABLE. WANDERS AWAY. MENINGITIS AT 2 YEARS. PARTIAL RIGHT-SIDED PARALYSIS. BAD HEREDITY. SPEECH DEFICIENT. TRANSFERRED FROM NORMAL SCHOOL TO SPECIAL SCHOOL.

DIAGNOSIS. MIDDLE GRADE IMBECILE OF MICROCEPHALIC TYPE.

PROGNOSIS. UNFAVOURABLE.

REMARKS.

FIGURE 6. ILLUSTRATIVE DIAGNOSIS CARD.

NAME. M. S. FEMALE.		SCHOOL.	
DATE OF BIRTH. 25/3/02.		AGE. 14 YEARS.	
BRAIN CAPACITY.		PERCENTILES.	
HEAD LENGTH.....	189 MM.		
HEAD BREADTH.....	157 MM.		
HEAD HEIGHT.....	129 MM.		
CUBIC CAPACITY OF BRAIN.....	1455 CC.	92.	
PHYSICAL AND PSYCHOPHYSICAL TESTS.		PERCENTILES.	
STANDING STATURE.....	159.0 CM.	66.	
SITTING STATURE.....	84.5 CM.	70.	
WEIGHT.....	49.2 K.	67.	
PHYSICAL AVERAGE.....		68.	
RIGHT GRIP.....	25. K.	35.	
LEFT GRIP.....	19. K.	20.	
VITAL CAPACITY.....	2300 CC.	34.	
PSYCHO-PHYSICAL AVERAGE.....		35.	
PSYCHOLOGICAL TESTS.		QUOTIENTS.	
BINET AGE.....	11 YEARS.	78.	
PORTERUS AGE.....	9 YEARS.	64.	
CLASS AGE.....	10 YEARS.	71.	
AVERAGE QUOTIENT.		71.	

PERSONAL.

MENTALLY UNSTABLE. STEALS. LIES. SEX PROBLIVITIES. FAIR EDUCATIONAL ATTAINMENTS BUT WITH NO SUSTAINED EFFORT.

DIAGNOSIS. A HIGH GRADE MORON OF THE MACROCEPHALIC TYPE.

PROGNOSIS. A DELINQUENT AND PROSTITUTE UNLESS CONTROLLED NOW.

REMARKS.

Table of Correlations (Males)

A.	Porteus Test Age and Industrial capacity	$r = .67$	p. e. = .069
	“ “ “ “ Social “	$r = .55$	p. e. = .086
	“ “ “ “ Educational “	$r = .27$	p. e. = .116
<hr/>			
B.	Binet Test Age and Industrial capacity	$r = +.62$	p. e. = .077
	“ “ “ “ Social “	$r = +.5$	p. e. = .094
	“ “ “ “ Educational “	$r = +.64$	p. e. = .074
<hr/>			
C.	Total Army Test Age and Industrial cap.	$r = +.61$	p. e. = .078
	“ “ “ “ “ Social “	$r = +.61$	p. e. = .078
	“ “ “ “ “ Educat'n'l “	$r = +.20$	p. e. = .120
<hr/>			
D.	Average Binet, Porteus and Industrial cap.	$r = +.77$	p. e. = .051
	“ “ “ “ “ Social “	$r = +.66$	p. e. = .071
	“ “ “ “ “ Educat'n'l “	$r = +.47$	p. e. = .098
<hr/>			
	Binet and Porteus	$r = +.21$	p. e. = .119

Table of Correlations (Girls)

Porteus and Industrial	$r = .75$	p. e. = .045
“ “ Social	$r = .73$	p. e. = .048
“ “ Educational	$r = .59$	p. e. = .066
<hr/>		
Porteus and Binet	$r = .60$	p. e. = .065
<hr/>		
Binet and Industrial	$r = .66$	p. e. = .058
“ “ Social	$r = .59$	p. e. = .066
“ “ Educational	$r = .81$	p. e. = .035

Diagnostic Rules

Acting on the above evidence it is evidently permissible to combine the Binet and Porteus mental ages. Individuals with a Binet-Porteus average I. Q. below 75 may be regarded as potential social inefficients. The assumption with regard to these cases is that their intellectual retardation or their mental instability is so grave as to render it most unlikely that they will ever make their way unaided in society. Using Healy's terms, they may be described as mental defectives, who do not possess abilities making for social success.

Children with Binet-Porteus I. Q.s from 80 to 75 may be diagnosed, tentatively, as border-line cases though their actual status would in a great number of cases be determined by the application of our full examination method. Children as dull as these, who have, for instance, a brain capacity

below the ten percentile of our tables must have restricted potentialities for further development, so that in their cases this evidence makes the diagnosis almost certain. Children who have a poor psychophysical rating, along with such a grave intellectual retardation, are also constitutionally inferior and are more unlikely, therefore, to earn their own livings.

Advantages of Our Method

The raising of the border-line of normality from an uncertain diagnostic level of 70 I. Q., per Binet, to a far more definite diagnostic level of 75, per Binet-Porteus, the determination of the status of a number of border-line cases, and the closer delimiting of border-line frontiers are, we believe, measurable advances in mental diagnosis, which are attained by the use of our method.

It will be observed that the diagnostic term "potential social inefficient" puts the emphasis on the social criterion, and further postpones all question of the curability, or otherwise, of the condition until mental development has ceased, and yet at the same time points the need of remedial or control measures for the conservation of the individual or the protection of society.

Table 33 gives the individual I. Q. s of some of the thousand children examined by Porteus in 1916. These the examination proved to have markedly subnormal mental levels. The number of children with average I. Q. s below 75 was 22, equaling 2.2 per cent. of the total; the number of border-line cases was 11, or 1.1 per cent. The Binet I. Q. s of the potential social inefficients ranged from 54 to 79, 8 of them having I. Q. s below 70, the limit of normality proposed by Terman. The Porteus I. Q. s ranged from 48 to 82, and the class quotients ranged from 53 to 86.

Results and Conclusions

1. The brain is the physical organ of mind. As mental development is conditioned by brain capacity, striking deviation from the normal in brain size will tend to be associated with mental abnormality.

2. Post-natal cerebral development is apparently chiefly concerned with the maturing of the supra-granular, educative, or controlling layer of the cerebral cortex. Very marked deficiency in cerebral capacity would thus appear to indicate a comparative lack of development of this important layer, and a consequent mental or moral insufficiency.

3. Observations of brain capacity are robbed of this significance in certain cases on account of variable factors for which head measurements can not allow. The chief of these are the varying ratios of meninges, cerebro-spinal fluid, and neuroglia (non-nervous tissue supporting the neurones or nerve cells). To these physical sources of error must be

Table No. 33

I. Q.s OF BORDER-LINE AND SOCIALLY INEFFICIENT GROUP. SELECTED FROM 1000 CASES.
(Porteus, 1916.)

Class No.	Binet I. Q.	Porteus I. Q.	Average I. Q.	Class I. Q.
263	68	71	70	66
374	54	48	51	60
591	74	63	69	67
602	71	60	66	66
655	73	73	73	53
726	72	55	64	75
771	67	67	67	78
673	76	69	73	66
368	67	79	73	74
575	73	69	71	78
667	76	69	73	70
740	76	64	70	77
800	69	71	70	78
728	76	67	73	74
494	70	71	71	82
852	69	66	68	81
57	73	72	73	85
418	66	82	74	79
857	76	61	69	86
430	78	60	69	81
36	78	63	71	83
446	79	65	72	86
449	77	74	76	75
363	73	79	76	74
16	75	75	75	70
413	76	78	77	83
992	76	74	75	90
805	74	77	76	85
349	72	83	78	79
258	73	82	78	79
674	69	80	75	66
725	76	73	75	80
534	76	74	75	80

added the imperfections of the mathematical mode of the calculation.

4. In consequence of the known sources of error the authors only consider marked deviation from the normal as of diagnostic value. Their brain capacity data are, therefore, arranged, for practical purposes, in the form of percentile tables which permit of the comparison of the individual with his own age group.

5. Examination of these tables shows:—

(a) That the average brain capacities of the mentally defective, deaf and dumb, criminal, and Australian Aboriginal are less than those of the corresponding normal age groups, which is in accordance with the principle on which this work is based.

(b) That girls, in accordance with all other sexual differences of growth and physical proportions, have a less brain capacity than the boys at every period of life in which the comparison is made.

(c) That in both the pre-pubescent and pubescent periods the girls' brain growth is relatively more rapid than the boys'. The boys' brain growth in the post-pubescent or adolescent period is apparently greater and, in point of time, is probably longer continued than the girls'.

(d) So far as the present work admits of the comparison—from the ninth to the fourteenth years—boys of a better social grade have an advantage in brain capacity.

6. Mental examination of unselected children in the 10 percentile (brain capacity) of their age group shows that about 50 per cent. are at dull or feeble-minded levels, and 5 per cent. above the average intelligence. Of children in the 90 percentile 14 per cent. are of subnormal intelligence, and 25 per cent. above normal.

7. Correlations found by Doll for defectives between psychophysical tests and mental age were found to be higher than those obtained with normal children. The nearer the individual approaches normal levels the less the tests partake of the nature of mental tests. The correlations are sufficiently high to warrant their retention as diagnostic aids. Better class children show an advantage over lower class children in these tests, the advantage being more pronounced in the cases of boys than girls. Girls show a relative improvement at 12 years of age.

8. The results of an examination of 1000 children by Terman's revision of the Binet-Simon scale show the following points:—

(a) Both the Binet and Porteus tests are either too easy for the lower years and too difficult for the upper years, or else young city children show a relative advance in intelligence up to 8 years and retardation after 9 years.

(b) A comparison of our results with Terman's shows a slightly larger percentage (3.1 per cent.) distinctly advanced. The percentage

classed by us as dull is distinctly above Terman's (15 per cent. as against 10 per cent.), but below Goddard's estimate of 18 per cent. as calculated from his tables. These differences may be in part due to differences in the social grade of the children examined.

9. The Porteus tests represent an attempt to evaluate socially valuable characteristics not fully tested by the Binet. These capacities are mainly prudence, forethought, planning capacity, ability to improve with practice, and adaptability to a new situation. Deficiencies in these respects, even more than in intellectual attainments, distinguish high grade defectives from normal children; hence the value of the tests for diagnostic purposes. They fulfil the requirements of supplementary tests because they can be standardized and arranged in the form of a scale. They can be easily applied, and they test highly correlated mental functions in simple situations, so that results may be readily interpreted. From investigations with large groups the following results accrue:—

(a) The correlation of the Porteus tests (old scoring) with the Binet is positive at each age level, ranging for boys, from .24 to .6, and for girls from .41 to .75.

(b) The boys' results are superior to the girls at every age up to 12 years. The girls' greatest annual increment in the average Porteus age occurs at 12 years, as is also the case with grip, vital capacity, brain capacity, and Binet age.

(c) In considering sex differences it is found that the middle class boys have a more pronounced advantage over the middle class girls than have the lower class boys over the lower class girls. The middle class boys have a decided advantage over the lower class boys up to 11 years. The middle class girls show a small average superiority over the lower class girls.

(d) The standardization of the revised Porteus tests has been tested with a large group of children. The average differences between mental and chronological ages for the 7 years from 6 to 12 years amount to about .25 of a year.

(e) The correlation between intelligence quotients per revised Porteus tests and the abbreviated scale amounts to .77. Between class standing and Porteus tests the correlations range from .18 to .46 for boys, and from .27 to .6 for girls.

The authors propose that cases should be regarded as "potential social inefficients" if the average of the Binet-Porteus quotients fall below 75. If the average Binet-Porteus I. Q. falls between 80 and 75 they are to be regarded as border-line cases.

It must be understood, however, that in each case the whole method should be applied in examination before final diagnosis be attempted, and

the results interpreted in the light of the social and educational history, and of the medical findings.

As thus applied, the authors believe that the combination method of diagnosis constitutes a practical advance on existing methods, and opens up new avenues of research amongst both the normal and abnormal members of the population. It must not be supposed, however, that the authors consider that their method covers the whole field of mental diagnosis. All that this monograph aims to do is to set forth what they regard as the minimum requirements of mental examination. For the great majority of cases such an examination will be sufficient to determine the mental status. In even the most difficult cases an invaluable light will be shed on their condition. At the same time, confirmation would, in such circumstances, be sought by the employment of other tests and by subjecting the case to more or less prolonged observation whilst under training.

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LIST OF PUBLICATIONS
FROM
THE RESEARCH LABORATORY OF THE TRAINING
SCHOOL AT VINELAND, N. J.

Psychology of the Normal and Subnormal. By Henry H. Goddard, Ph.D., Director of the Ohio Bureau of Juvenile Research, late Director of the Vineland Laboratory. Cloth, 8 vo., 349 pp. \$5.00, postpaid.

This is the latest book by a world-known author on mental subnormality and constitutes a most practical aid to the study of psychology. The first part of the book contains a clear and well-illustrated description of the physical basis of mind and its operations, and includes references to many recent advances in brain study.

In the second part, mental processes are described as they are found functioning throughout the whole range of mental development, from the subnormal to the normal. To the student of normal psychology the account of emotions, instincts, perceptions, habits of thought and action is well illustrated by the comparative study of these mental manifestations as they may be observed in their simpler relations in the feeble mind. On the other hand, the student who wishes to understand the defective mind is vastly aided by the description of normal mental development. No other book succeeds so well in serving the dual purpose of a textbook in normal and subnormal psychology.

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